EXPERIMENT MANUAL

RENEWABLE ENERGY LAB

HANDS-ON PROJECTS FOR THE CLEAN ENERGY FUTURE

THAMES & KOSMOS

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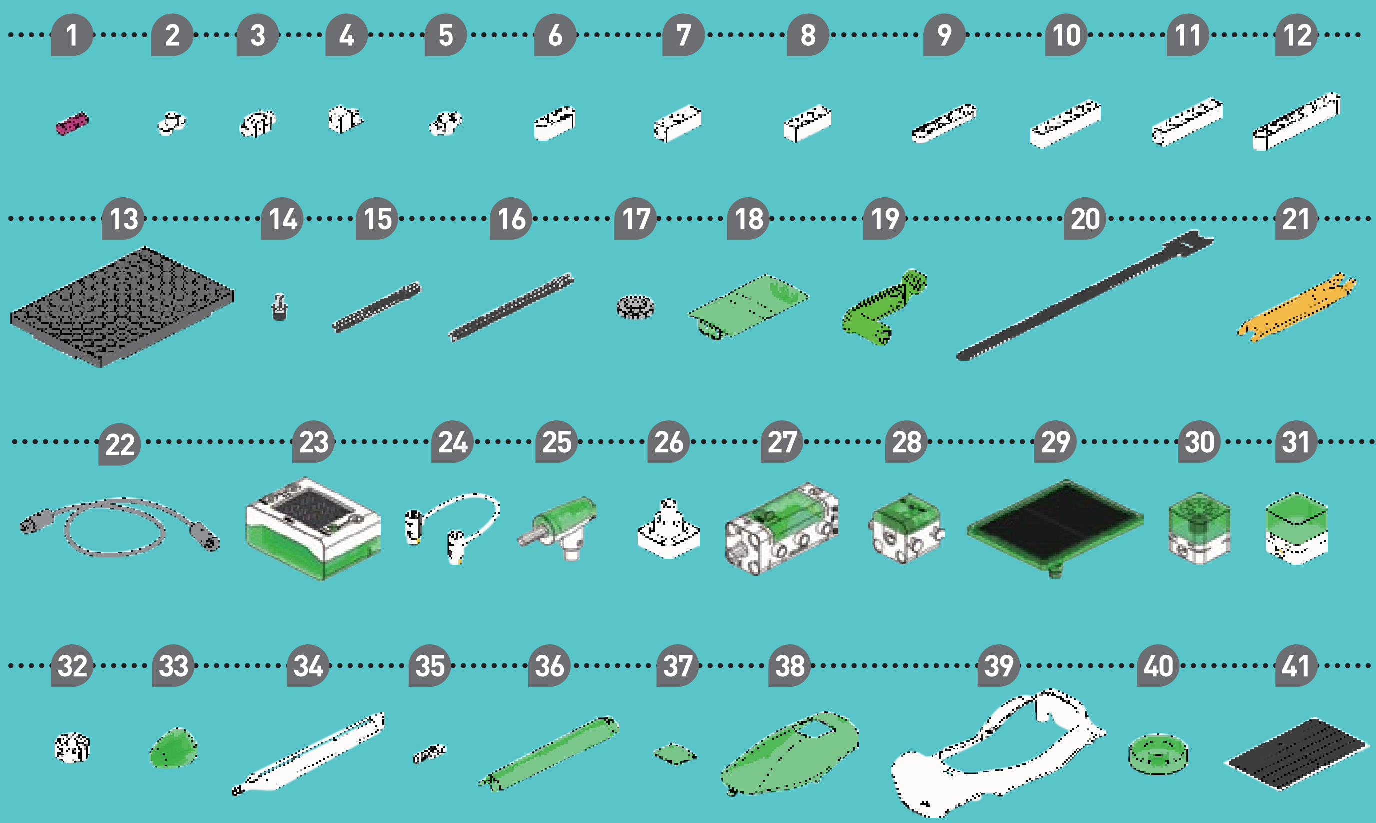
KIT CONTENTS

What's inside your experiment kit:



✓	No.	Description	Quantity	Item No.
○	1	Static axle connector	22	1187-W10-E1K1
○	2	Two-in-one converter	4	7061-W10-G1W2
○	3	Hinge	2	7061-W85-F1W1
○	4	90-degree converter, Y	8	7061-W10-Y1W2
○	5	Dual axis connector	2	7430-W10-B1W1
○	6	3-hole rounded rod	2	7404-W10-C1W1
○	7	3-hole cross rod	2	7026-W10-X1W2
○	8	3-hole rod	2	7026-W10-Q2W2
○	9	5-hole rod, flat	2	7443-W10-C1W1
○	10	5-hole rod	4	7413-W10-K2W2
○	11	5-hole cross rod	4	7413-W10-R1W2
○	12	7-hole rounded rod	7	7404-W10-C2W1
○	13	Base grid	1	7125-W10-A1SK1
○	14	Shaft plug	4	7026-W10-H1D1
○	15	70-mm axle	1	7061-W10-Q2D1
○	16	100-mm axle	1	7413-W10-L2D1
○	17	Gear	2	7026-W10-D2S2
○	18	Shell	2	7407-W10-D1TG
○	19	Crank	1	7326-W85-D1G
○	20	Strap	1	R33#1410
○	21	Part separator tool	1	7061-W10-B1Y

✓	No.	Description	Quantity	Item No.
○	22	Extension wire connector	1	1246-W85-D1
○	23	Green Energy Management System (GEMS)	1	1410-W85-A
○	24	Quick wire connector	3	1410-W85-B
○	25	Nacelle	1	1410-W85-C
○	26	Wind turbine base	1	1410-W85-D
○	27	Generator/motor	1	1410-W85-E
○	28	Supercapacitor	1	1410-W85-F
○	29	4.5-volt solar panel	1	1410-W85-G
○	30	Buzzer	1	1410-W85-H
○	31	LED holder	1	1410-W85-I
○	32	Rotor blade hub	1	1410-W10-B3W
○	33	Nose cone	1	1410-W10-G3TG
○	34	Rotor blade	3	1410-W10-C2W
○	35	DIY blade connector	6	1410-W10-C1W
○	36	Wind turbine tower	2	1410-W10-G2TG
○	37	Car sunroof	1	1410-W10-I3TG
○	38	Car shell top	1	1410-W10-I1TG
○	39	Car shell base	1	1410-W10-E1W
○	40	Car wheel	4	1410-W10-I2TG
○	41	Foam sticker sheet	1	R32#1410

Yay!
Let's begin!

YOU WILL ALSO NEED: *3 AAA batteries (1.5-volt, type LR03), small Phillips-head screwdriver, 60-watt halogen lamp, electric fan, plastic bottle, scissors*

TABLE OF CONTENTS

TEACHERS!

SCAN THIS QR CODE FOR **CLASSROOM RESOURCES,** INCLUDING **PRINTABLE PDFS** TO GUIDE STUDENT LEARNING.

THIS KIT IS COMPATIBLE WITH **NEXT GENERATION SCIENCE STANDARDS**

NGSS Science & Engineering Practices

- ✔ Planning & carrying out investigations
- ✔ Analyzing & interpreting data
- ✔ Using mathematics & computational thinking
- ✔ Constructing explanations & designing solutions
- ✔ Engaging in an argument from evidence
- ✔ Obtaining, evaluating & communicating information

NGSS Cross-Cutting Concepts

- ✔ Scale, proportion & quantity
- ✔ Energy & matter
- ✔ Structure & function
- ✔ Stability & change

NGSS Disciplinary Core Ideas

- ✔ ESS3.C Earth & Human Activity
- ✔ ESS3.D Global Climate Change

SAFETY INFORMATION

Warning!

Not suitable for children under 3 years. Choking hazard — small parts may be swallowed or inhaled. Strangulation hazard — long cables may become wrapped around the neck.

WARNING: This toy is only intended for use by children over the age of 8 years due to accessible electrical components. Instructions for parents or caregivers are included and shall be followed.

May only be operated when fully assembled. Proper assembly must be checked by an adult before use.

Safety for Experiments with Batteries:

» To operate this kit, you need three AAA batteries (1.5-volt, type LR03), which could not be included in the kit due to their limited shelf life. Inserting, removing, and replacing batteries should be done by an adult or under adult supervision.

» Avoid a short circuit of the batteries. A short circuit can cause the wires to overheat and the batteries to explode.

» Different types of batteries (e.g. rechargeable battery and non-rechargeable battery) or new and used batteries are not to be mixed.

» Do not mix old and new batteries.

» Do not mix alkaline, standard (carbon-zinc), or rechargeable (nickel-cadmium) batteries.

» Batteries are to be inserted with the correct polarity (+ and -). Press them gently into the battery compartment (see page 5). This page also explains how to insert, remove, and change the batteries.

» Non-rechargeable batteries are not to be recharged. They could explode!

» Rechargeable batteries are only to be charged under adult supervision.

» Exhausted batteries are to be removed from the toy.

» The supply terminals are not to be short-circuited.

» The wires are not to be inserted into socket outlets.

» Avoid deforming the batteries.

» Dispose of used batteries in accordance with environmental provisions, not in the household trash.

» Dispose of electrical equipment/electrical parts separately and in accordance with environmental regulations.

» The device is not to be connected to more than the recommended number of power supplies, this means only use the included battery box.

» Remove batteries from the device (GEMS) if it is not in use for an extended period.

Notes on Disposal of Electric and Electronic Components

The electronic components of this product are recyclable. For the sake of the environment, do not throw them into the household trash at the end of their lifespan.

They must be delivered to a collection location for electronic waste, as indicated by the following symbol:

Please contact your local authorities for the appropriate disposal location.

Dear parents and supervising adults!

Children want to explore, understand, and create new things. They want to try things and do it by themselves. They want to gain knowledge! They can do all of this with Thames & Kosmos experiment kits. With every single experiment, they grow smarter and more knowledgeable.

→ Before beginning the experiments, read through the instructions along with your child, discuss the safety notes, and keep them on hand for reference. Check to make sure that the models have been assembled properly, and be ready to help with the experiments.

→ Do not expose the toy to extreme heat or long periods of direct sunlight; protect it from heavy, persistent rain and frost.

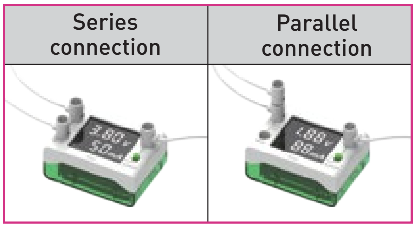
→ When conducting experiments using the charging and discharging module, please have an adult inspect the experiment or model to ensure that children have assembled it correctly.

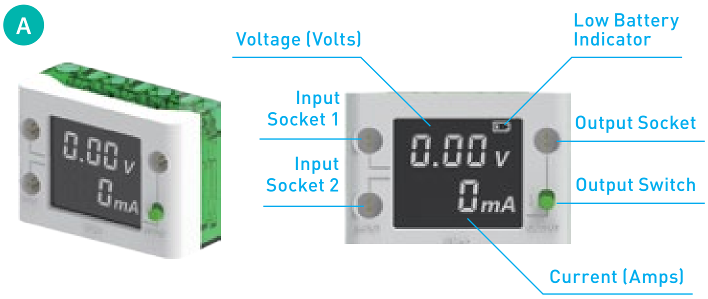
→ This kit includes one charging and discharging module (supercapacitor). You can charge the charging and discharging module through this kit. When operating, please be sure to do so under the supervision of parents or adults, and follow the instructions.

We hope you and your child enjoy experimenting while learning about the technology behind clean energy and all of its benefits!

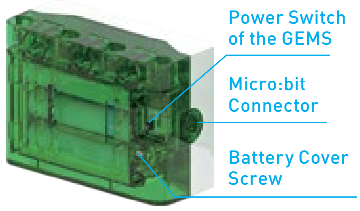
INTRODUCTION TO THE COMPONENTS

A. The **GEMS (green energy management system)** is a device capable of transmitting and monitoring electrical power. It can measure voltages ranging from 0.01 to 30 volts (V) and currents from 0 to 999 milliamperes (mA). It features two input terminals and one output socket at the top. When two easy wire connectors are connected to the two input terminals separately, the device measures the combined voltage of both (series connection). However, if both easy wire connectors are connected to the same input terminal, the device measures the higher voltage of the two (parallel connection).

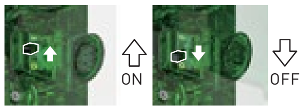




- Avoid touching the screen. Use a microfiber cloth to gently wipe off dust and dirt.
- Both Input Sockets 1 and 2 can be used. When both sockets have power input, the displayed voltage value will be the sum of both.
- To activate the output socket, turn on the output switch. The current value will only be displayed when there is power consumption.

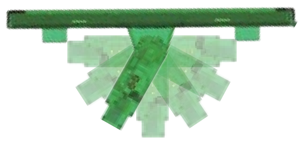


- Toggle the switch to turn on the GEMS. Please turn off the power after use.

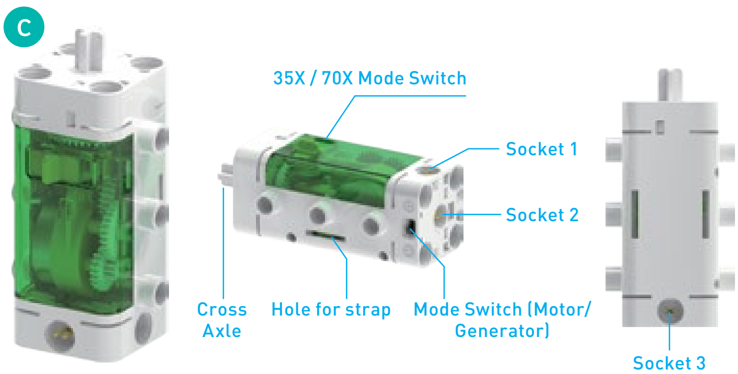


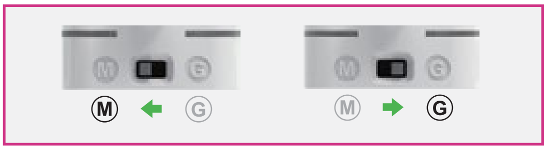
B. The angle of the **4.5V solar panel** can be adjusted according to the position of the light source. It converts solar energy or the energy from a 60-watt halogen lamp into electricity, simulating the power generation process of a solar power plant.

- The 4.5V solar panel can be adjusted to 11 different angles, in 18° intervals.
- The plug and socket are compatible and can be used simultaneously.
- Applicable range: 0V–4.5V.



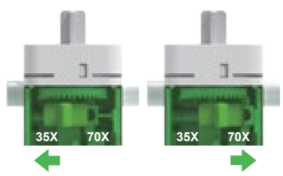
C. The **generator/motor** can switch between **generator (G)** or **motor (M)** modes using a switch. In generator mode, rotating the axle generates electricity, simulating the power-generation process of a **hydroelectric power plant** or **fossil fuel plant.** In motor mode, the axle rotates simply when electricity is supplied. Additionally, the generator/motor features a gear ratio switch, allowing you to switch between two gear ratios: 35X and 70X.



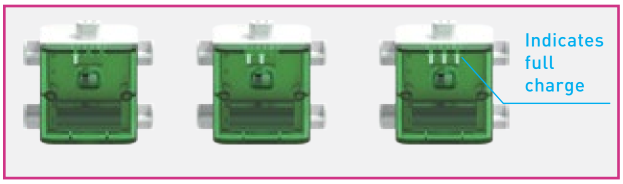


Before each experiment, determine whether you will be using motor mode or generator mode. Motor mode is represented by M and generator mode is represented by G.

- When switching between 35X and 70X, push until you hear a "click"; switch to the left for 35X and to the right for 70X.
- Sockets 1 to 3 are interconnected and can be used simultaneously.
- Motor mode applicable voltage: 0V–20V.

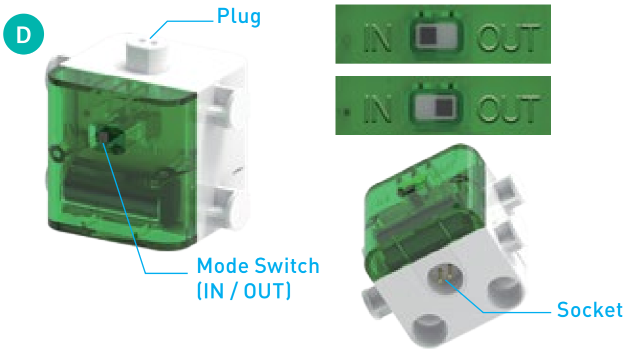


D. The **supercapacitor** functions similarly to a rechargeable battery, capable of both charging and discharging. It can switch between **charging (IN)** or **discharging (OUT)** modes using a switch. There are three indicator lights on the top to display the charge level during charging and the voltage during discharging. One light indicates approximately 2V; two lights indicate approximately 3V; three lights indicate approximately 4V. If no lights are on, it means the battery level is below 2V or there is no power input.



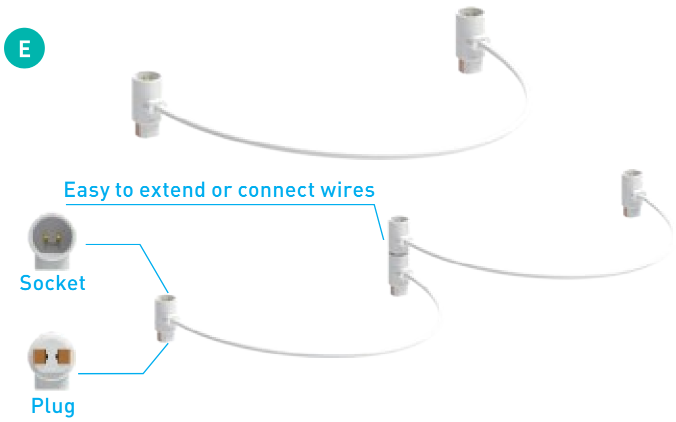
- The plug and socket are interconnected and can be used simultaneously.

- Switch to the left for "IN" mode to allow power input (charging); applicable range: 0V–20V.
- Switch to the right for "OUT" mode to allow power output (discharging); applicable range: 0V–4V.



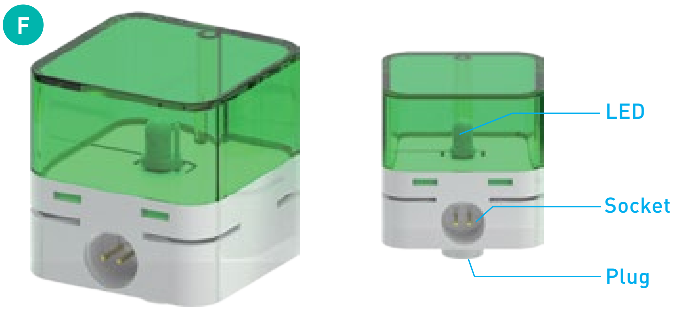
E. The **easy wire connector** can transmit electric current, and the male and female connectors on both sides can be connected to components such as wires, 4.5V solar panels, generator/motor, and supercapacitor.

Ensure that the connector's flat surfaces are aligned before assembly.



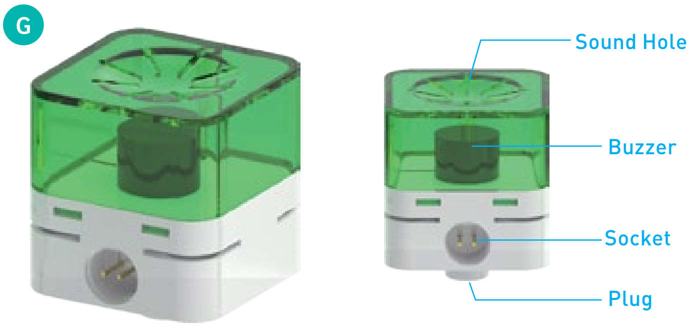
F. The **LED**, or Light Emitting Diode, emits white light when electricity passes through it.

- The plug and socket are interconnected and can be used simultaneously.
- Operating range: 2.6V–20V.



G. The **buzzer** emits a single-tone sound when electricity passes through it. If the voltage is not sufficient, the buzzer may not be activated.

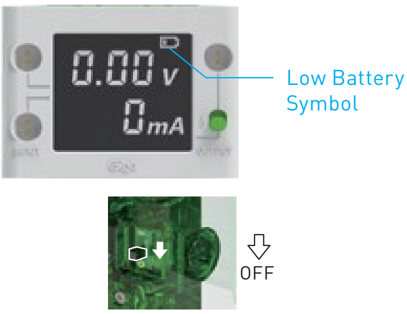
- The plug and socket are interconnected and can be used simultaneously.
- Operating range: 1.6V–20V.



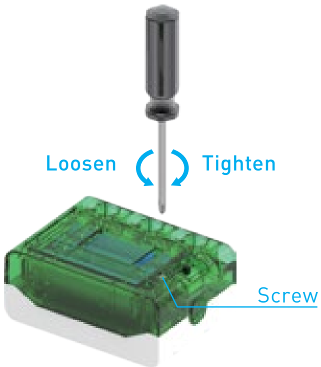
INSTALLING BATTERIES

When using for the first time or when the low battery symbol is displayed on the screen, please replace the batteries.

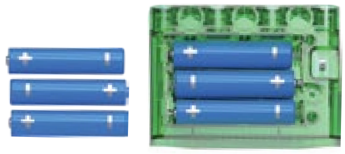
- Note: Please turn off the power before replacing the batteries.



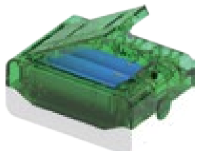
1 Use a screwdriver (PH00, PH0, PH1) to open and close the battery compartment. Turn counterclockwise to loosen and clockwise to tighten.



2 Insert 3 AAA batteries (1.5 volts, type LR03), paying attention to the battery polarity as shown.

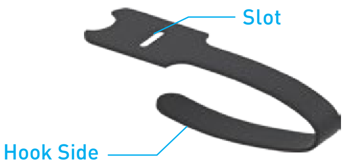


3 Cover the battery compartment and tighten the screws to start using the device.

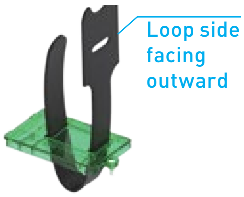


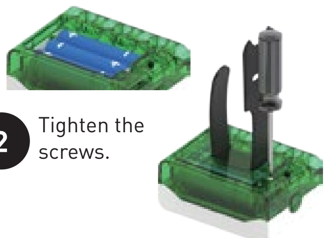
ATTACHING THE STRAP TO GEMS

- Attach the strap to the model to test its performance in specific environments. Note: Avoid conducting tests in damp or harsh weather conditions.
- The strap has two sides, one with a soft, fuzzy texture (loop side) and one with a slightly rough texture (hook side).
- Pay attention to the two ends of the strap: the larger end has a slot, and the other thin end can be threaded through the slot to allow the loop and hook sides to adhere.



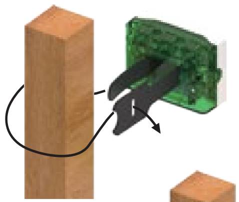
1 Turn off the power, unscrew the battery cover of the GEMS, and thread the thin end of the hook and loop fastener through.



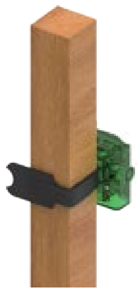


2 Tighten the screws.

3 Find a sturdy pole, wrap the fastener around the pole, and thread the thin end through the slot.

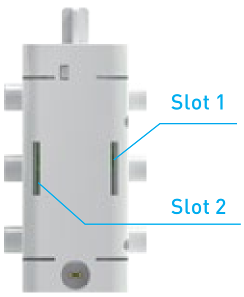


4 Adjust the tightness of the strap until secure.



ATTACHING THE STRAP TO GENERATOR\MOTOR

1 The generator/motor has two slots on the back for the strap.



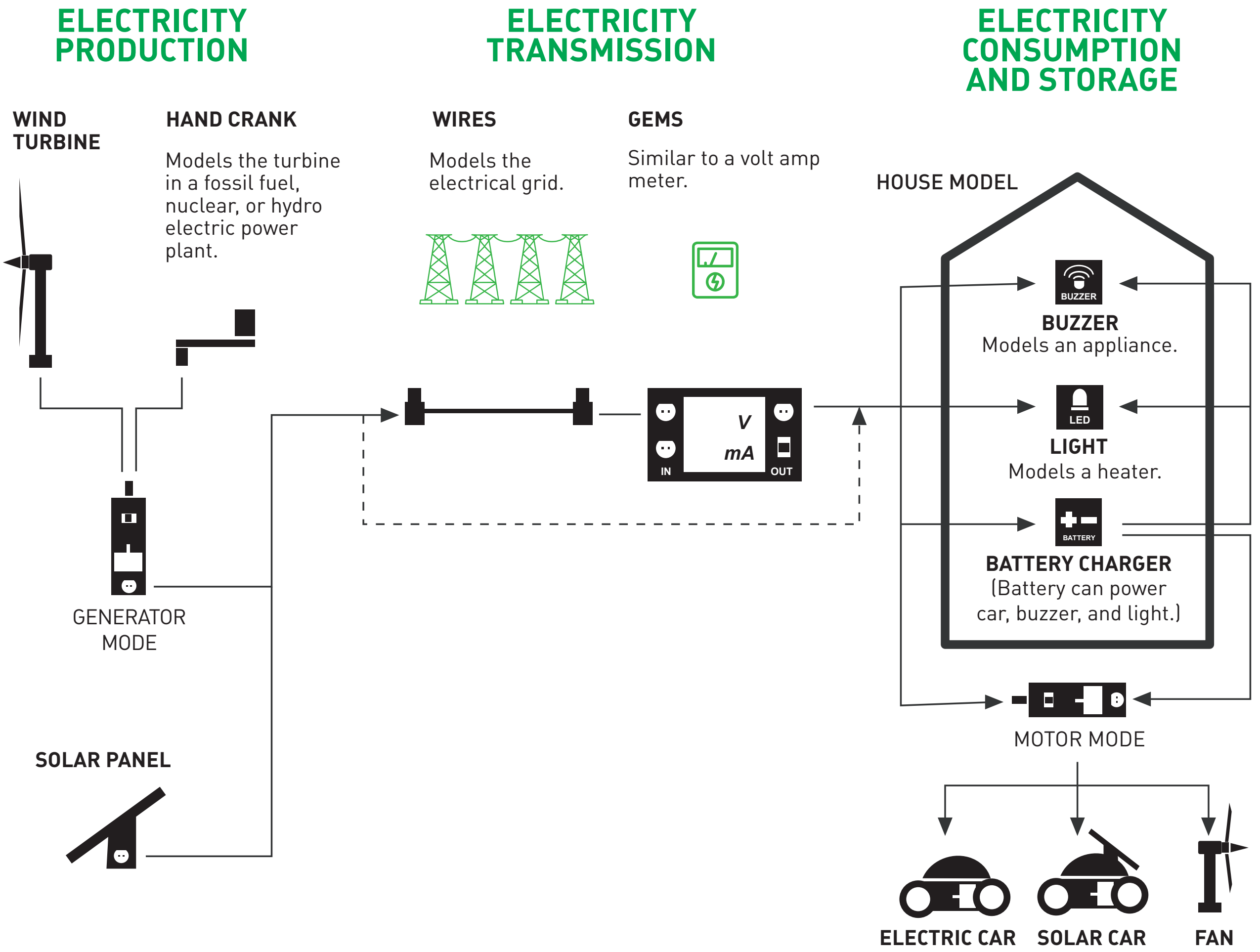
2 Rotate the generator/motor to a 45-degree angle to the right, wiggle the strap left and right, and slowly thread the thin end into slot 1.

3 Thread the thin end into the slot 2, find a sturdy pole, and thread the thin end through the slot in the strap.

MODELING ENERGY IN DAILY LIFE

Modern life is closely intertwined with energy. Since the industrial revolution in the late 19th century, the world's electricity has been generated at power plants. Today, about 60% of electricity is generated using fossil fuels (coal, oil, and natural gas), which are burned in order to heat water to create steam to turn a turbine. The turbine drives an **electromagnet** that generates electricity. But burning fossil fuels contributes harmful greenhouse gases to Earth's atmosphere, which is contributing to a changing climate. Therefore, **renewable energy sources** that impose minimal burden on the environment are growing in importance and popularity. In this kit, you will learn about diverse forms of renewable energy, understand their advantages over nonrenewable sources, and explore the potential challenges they may face in future developments.

The topic of energy can be divided into three parts: **generation of electricity, transmission of electricity, and the use and storage of electricity**. Below is a schematic of the parts included in this kit, and the real-life components that they model.



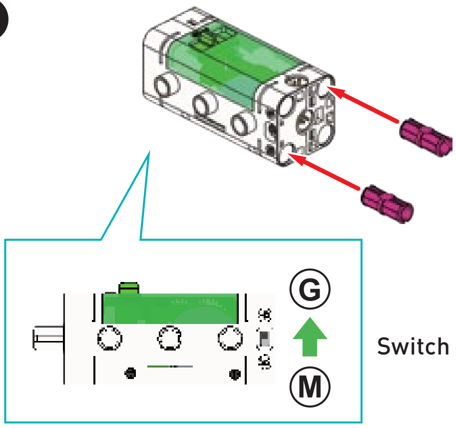
PART 1: GENERATION OF ELECTRICITY

Electricity is just one of those things. Normally, you don't see it, and you only recognize it by the effect it has. But you come across electricity every day — when you turn on the light or make a piece of toast. So what makes electricity flow?

Electricity consists of the movement of unbelievably tiny particles known as **electrons** — which are much smaller than an atom. It can be generated through various methods such as solar power generation, hydroelectric power generation, wind power generation, and more. In this kit, you can generate electricity using two components: a **generator/motor** and a **4.5V solar panel.**

EXPERIMENT 1: HAND CRANK FLASHLIGHT

1

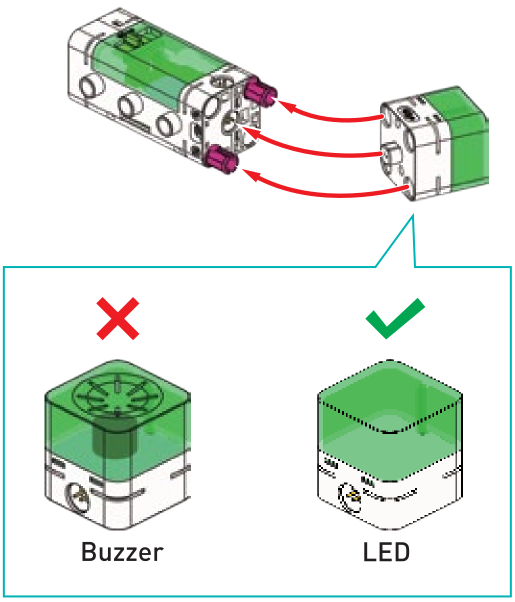


Switch to G mode

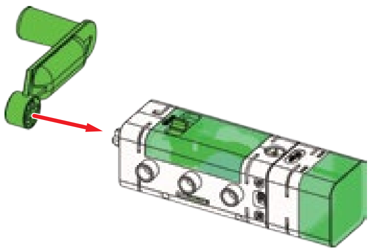
2

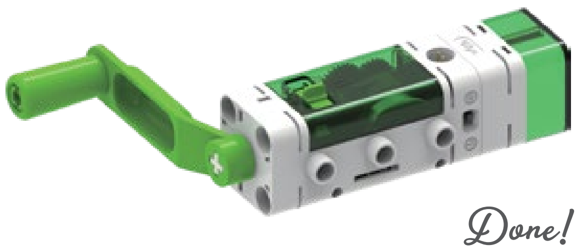
NOTE

Ensure that the connector's flat surfaces are aligned before assembly.



3





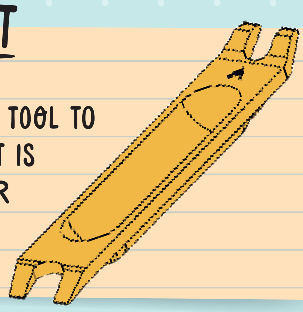
Turn the crank handle to operate the flashlight.

TIP

TEST THE HAND CRANK FLASHLIGHT IN A DARK ENVIRONMENT TO SEE HOW FAR ITS LIGHT CAN ILLUMINATE OBJECTS.

IMPORTANT

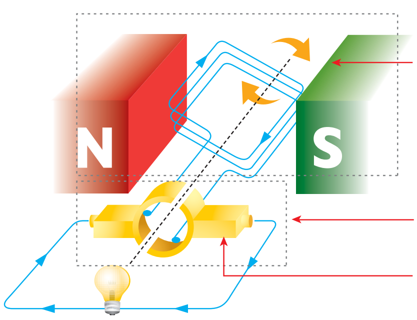
USE THE PART SEPARATOR TOOL TO TAKE MODELS APART. IT IS ESPECIALLY HELPFUL FOR PRYING AXLE CONNECTORS OUT OF HOLES.



WHAT'S HAPPENING?

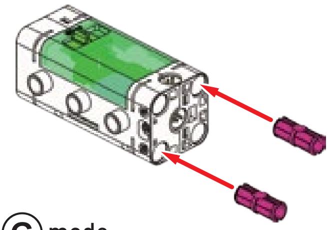
Electromagnetic Induction

Electromagnetic induction was first discovered by Michael Faraday. When there is a change in the magnetic field inside the coil, a current is induced in the coil. The internal components of a generator include a magnet to generate a magnetic field and a coil that rotates. When we rotate the handle clockwise, it causes a change in the magnetic field inside the coil, generating a current to light up the LED bulb.



EXPERIMENT 2: HAND CRANK BUZZER

1

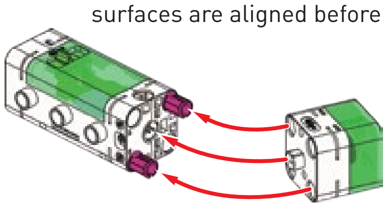


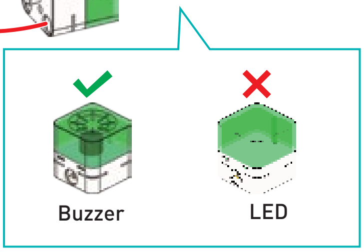
Switch to (G) mode

2

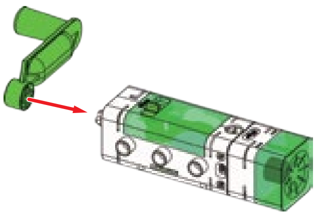
NOTE

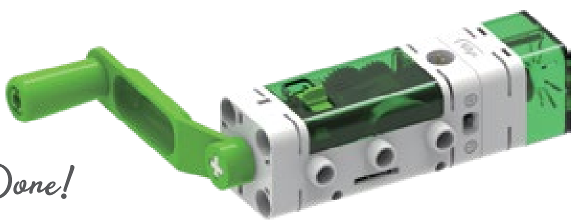
Ensure that the connector's flat surfaces are aligned before assembly.





3





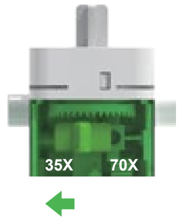
Done!

Turn the crank handle to operate the buzzer.

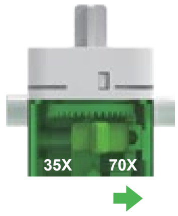
WHAT'S HAPPENING?

Inside a buzzer there is a vibrating element similar to the vocal cords in our throat. When current passes through the vibrating element, it generates sound waves through vibrations, allowing us to hear sound. Everyday speakers and audio systems also use this principle to produce sound. Try touching your throat while speaking; can you feel your vocal cords vibrating?

EXPERIMENT 3: CHANGING THE GENERATOR GEAR RATIO

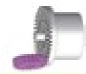


Switch to 35X mode



Switch to 70X mode

By using the switch on top of the generator/motor, you can make the generator rotate at two different gear ratios: 35:1 or 70:1. Try experimenting to see what happens when you rotate the handle clockwise under these two different gear ratios.

Gear ratio	Force required for rotation	Brightness of the LED	Sound of the buzzer	Gear Setting
35X	Less (Effort-saving)	Dimmer	Quieter	
70X	More (Effort-consuming)	Brighter	Louder	

WHAT'S HAPPENING?

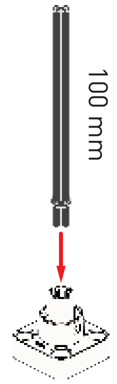
According to the law of electromagnetic induction, the strength of the current is related to the rate of change of the magnetic field within the coil. When the coil's rotation speed increases, the rate of change of the magnetic field inside the coil increases, generating a larger current, and vice versa.
In experiment 3, when we switch to the 35X gear ratio, we can turn the large handle more easily, but this also causes the coil to rotate more slowly, resulting in a dimmer LED and a quieter buzzer. When we switch to the 70X gear ratio, the crank requires more effort to turn, but this causes the coil to rotate faster, resulting in a brighter LED and a louder sound from the buzzer.

TIP

TRY ROTATING THE HAND CRANK BUZZER AT DIFFERENT SPEEDS AND LISTEN CAREFULLY TO HOW THE SOUND CHANGES.

EXPERIMENT 4: WIND POWER GENERATION

1



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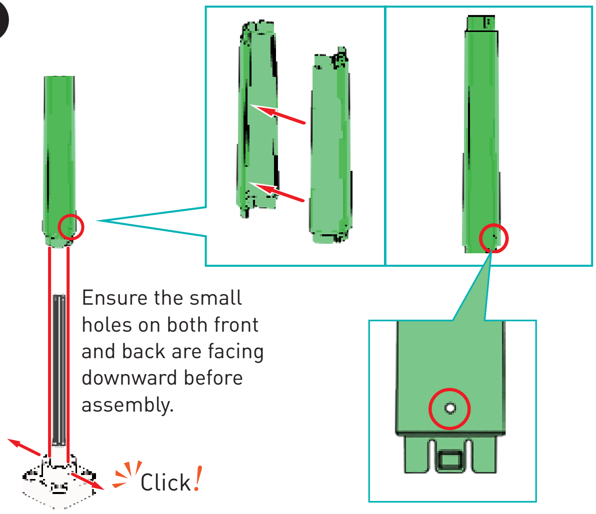
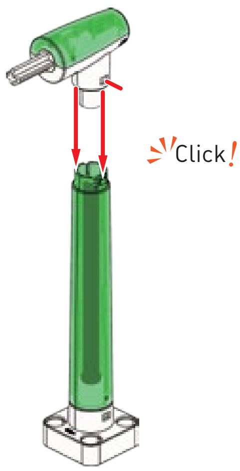


Ensure the small holes on both front and back are facing downward before assembly.

3



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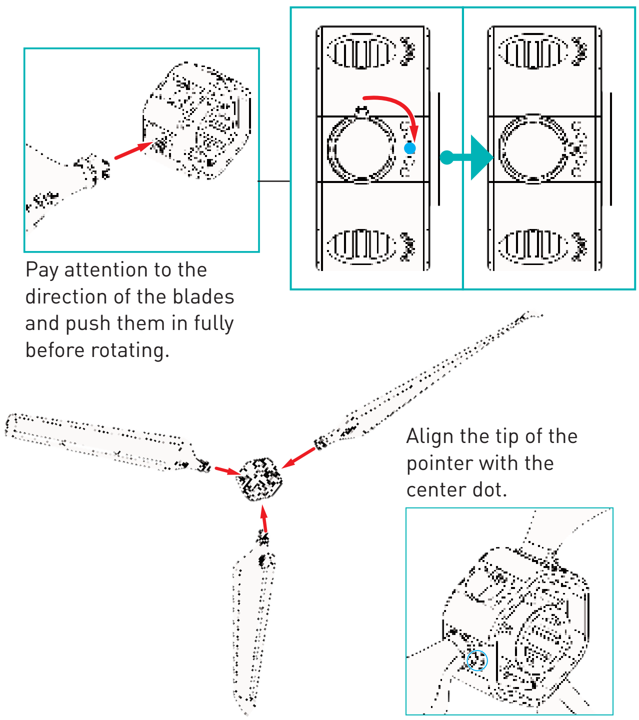
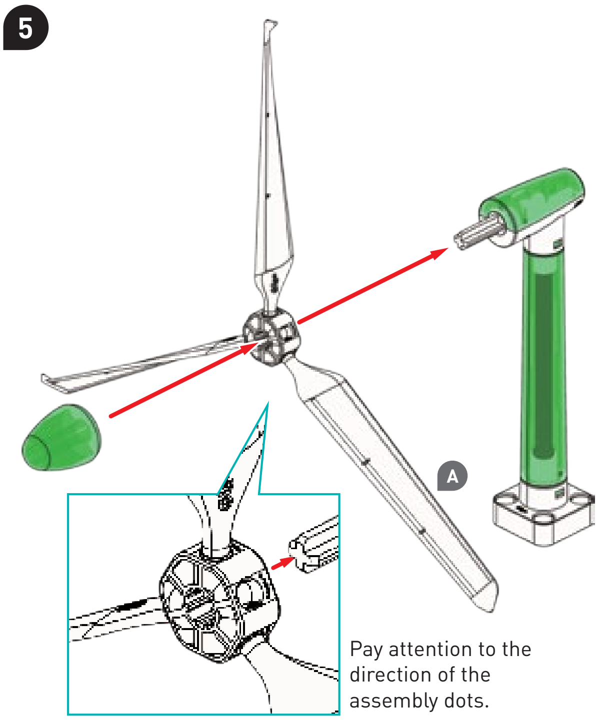


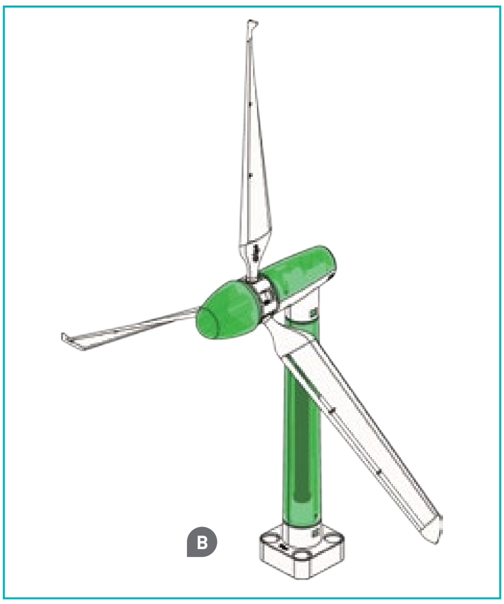
Pay attention to the direction of the blades and push them in fully before rotating.

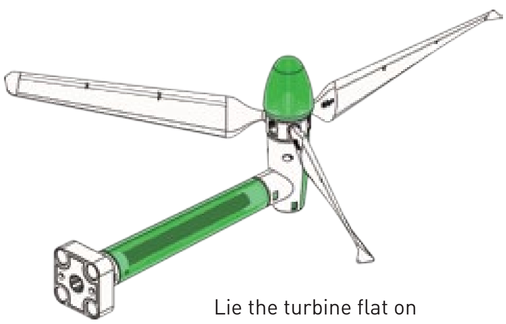
Align the tip of the pointer with the center dot.

5



Pay attention to the direction of the assembly dots.



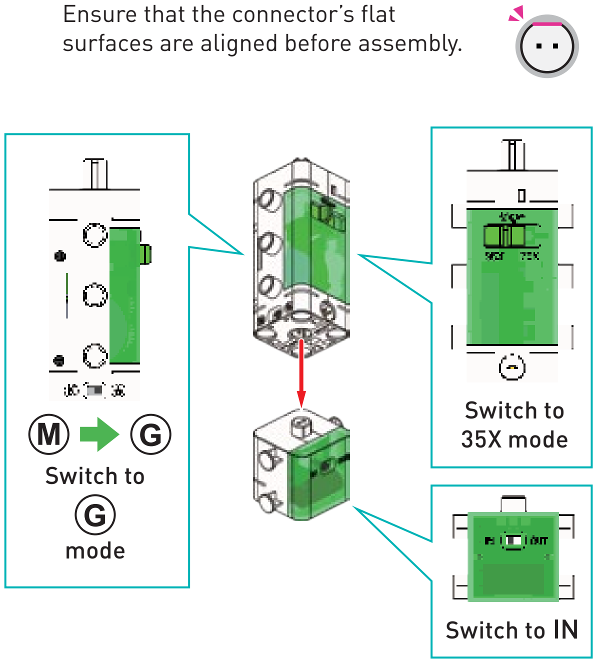


Lie the turbine flat on the table.

6

NOTE

Ensure that the connector's flat surfaces are aligned before assembly.



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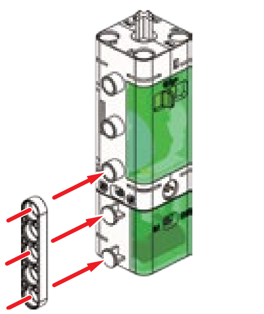

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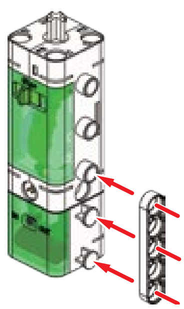

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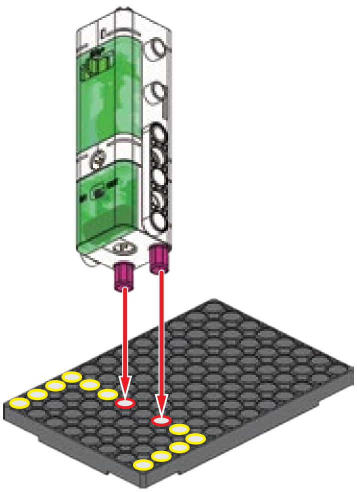
10



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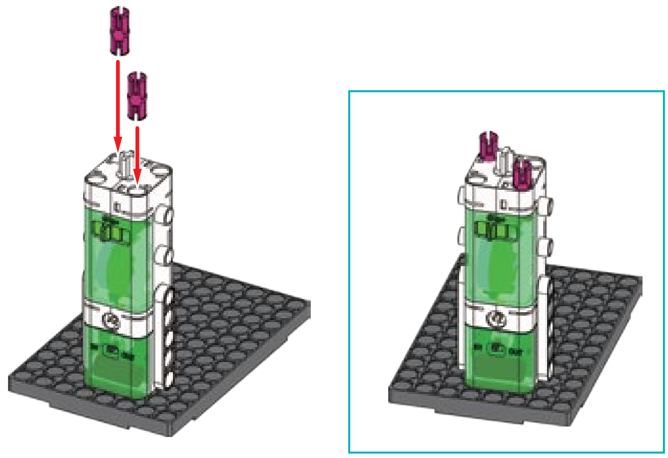


12

Done!

WHAT'S HAPPENING?

We've completed a wind power generation device! Try experimenting by using wind power to charge the supercapacitor. First, switch the supercapacitor to charging mode and the generator/motor to generator mode. Then, use an electric fan to blow air on the model. When the indicator light on the supercapacitor lights up, it means we've successfully stored electricity generated by the wind. You can also use the strap to secure the wind power generation device, ensuring the model remains stable during charging.

CHECK IT OUT

MOTORS AND GENERATORS

A **motor** converts electrical energy into kinetic energy. It uses electricity to power moving parts. A **generator** works in exactly the opposite way. It uses motion to generate electricity. This means that when the wind turbine rotates, the generator converts kinetic energy into electrical energy. Motors and generators both use electromagnetic induction to convert energy from one form to another.

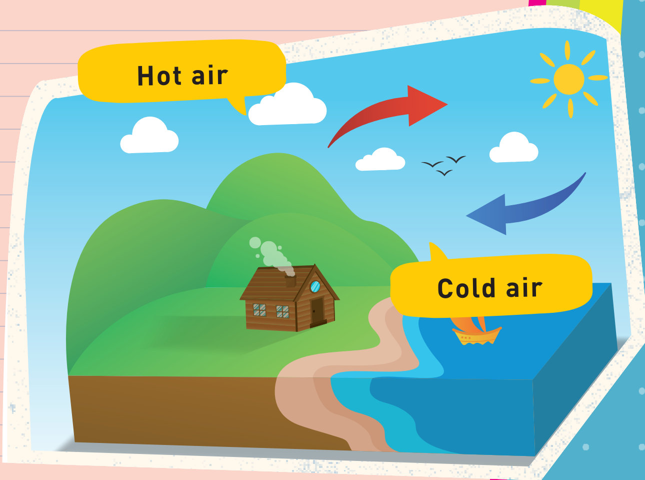
IS IT A MOTOR OR A GENERATOR?

The cool thing about electric generators is that they can also be used as motors. The only difference is in the way the component is used:

- If electricity flows through the component, it is a motor. The electricity rotates the axle.
- If the axle is rotated manually — i.e. by the hand crank or by wind — it is a generator. Electrical energy is generated.

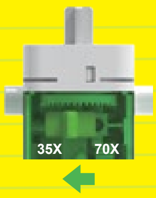
How is wind formed?

Our planet is protected by a layer of gases called the atmosphere, which blocks cosmic radiation and provides us with air for breathing. Wind is air that is moving predominantly in a particular direction. But, how does air move? When sunlight shines onto the Earth, the solar heat causes the air on the Earth's surface to warm up, expand, and decrease in density. This results in warm air rising, creating an empty space for cold air to move in and fill it up. This movement of air is what we refer to as wind.

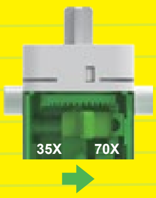


GO FURTHER!

1. Try experimenting by switching the gear ratio of the generator/motor to either 35X or 70X, and test which gear ratio is more efficient at charging the supercapacitor.

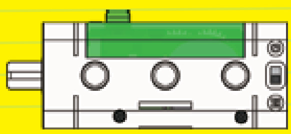


Switch to 35X mode

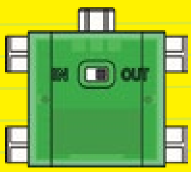


Switch to 70X mode

2. Transform the wind power generation device into an electric fan by switching the supercapacitor to discharging mode and the generator/motor to motor mode. Use the stored electricity to power the fan and make it rotate.

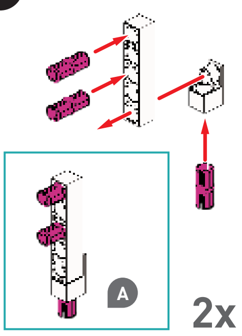


Switch to M mode



Switch to OUT

EXPERIMENT 5: SOLAR-POWERED BUZZER

1


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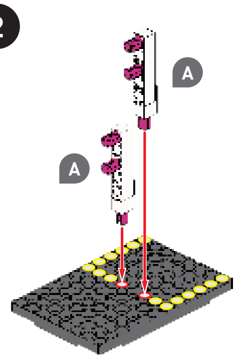

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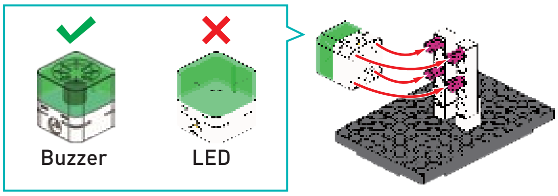
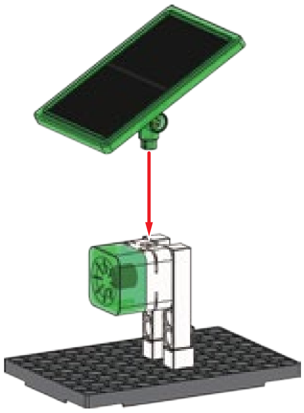


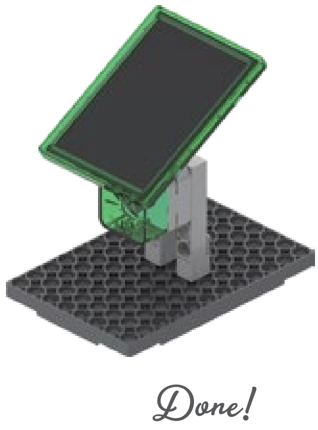
4

NOTE

Ensure that the connector's flat surfaces are aligned before assembly.



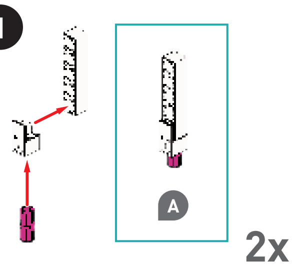
Solar-Powered Buzzer



WHAT'S HAPPENING?

Switch the supercapacitor to charging mode, and place the model outdoors on a sunny day. When the sunlight intensity is sufficient, the solar-powered buzzer will sound. The top layer of the solar cell is made of silicon, which captures light well. The captured light contains small particles that carry energy, called **photons.** These photons move through the solar cell and hit another layer that contains **electrons** — tiny particles in the solar cell that can carry electricity. When the photons hit the electrons, the electrons break away from their original positions. The movement of the electrons creates a flow of electricity — or **current.** The more sunlight that hits the solar cell, the more electricity is generated.

EXPERIMENT 6: SOLAR CHARGING DEVICE

1


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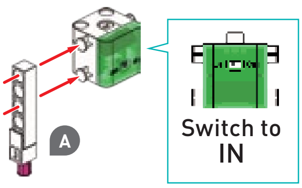

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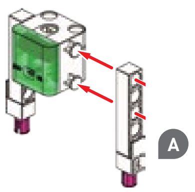

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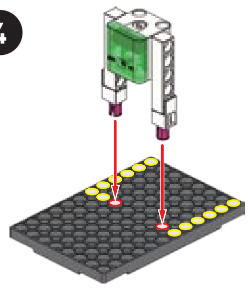
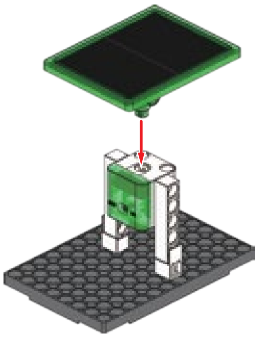


5

NOTE

Ensure that the connector's flat surfaces are aligned before assembly.



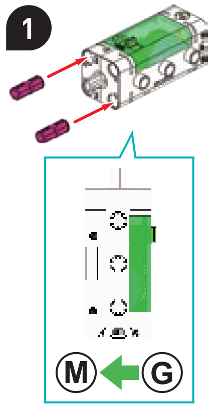
Solar Charging Device

WHAT'S HAPPENING?

You can place the solar charging device outdoors on a sunny day to allow the solar panel to charge the supercapacitor.

EXPERIMENT 7: SOLAR-POWERED FAN

1

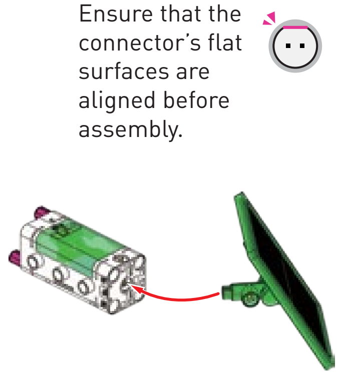


Switch to M mode

2

NOTE

Ensure that the connector's flat surfaces are aligned before assembly.



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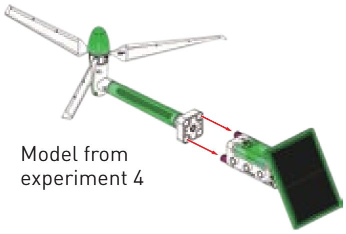
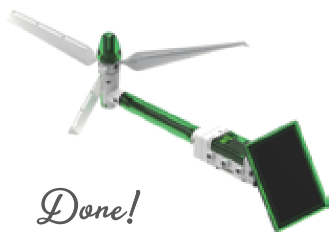


Model from experiment 4

Solar-Powered Electric Fan



WHAT'S HAPPENING?

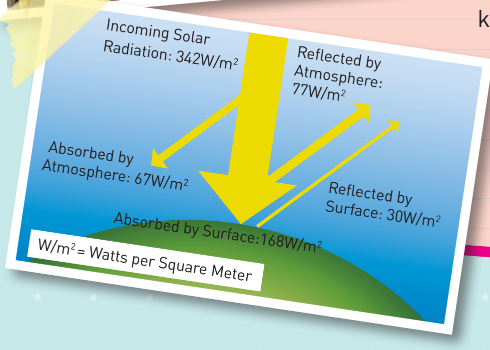
We've completed a solar-powered electric fan! Switch the generator/motor to motor mode. When sunlight or a 60-watt halogen lamp shines on the 4.5V solar panel, the fan will rotate to produce a nice breeze.

CHECK IT OUT

Solar panels are becoming increasingly common, because solar cells convert the renewable resource of sunlight into electricity. Look around your neighborhood or city, and you may see solar panels on rooftops or in arrays. With the right infrastructure to effectively store energy, we can harness the sun's energy to meet our energy needs.

GO FURTHER!

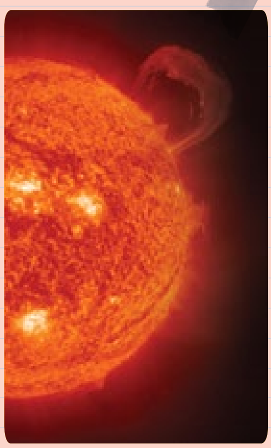
1. Experiment with using a 60-watt halogen lamp to power the model and observe the response of the supercapacitor.
2. Place the solar-powered buzzer outdoors at different times of the day and observe when the model emits sound.
3. Place different objects on the ground, such as cotton, scraps of paper, pencils, etc., and attempt to use the wind generated by the model to blow them around.



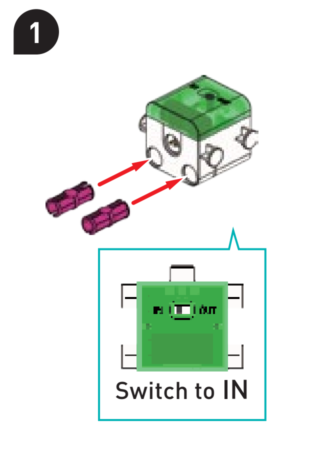
Amazing Energy Storage

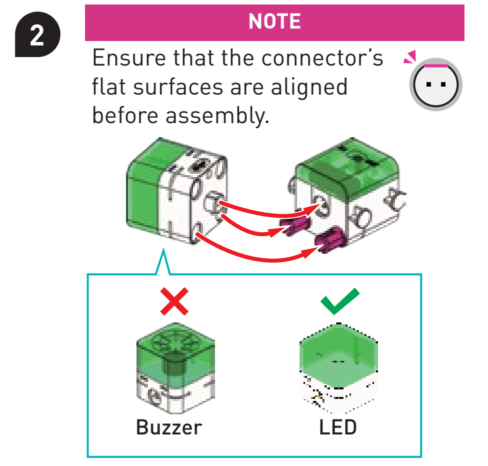
Every year, about 1,500,000,000,000,000,000 kilowatt-hours of solar energy enter the Earth's atmosphere, which is equivalent to 10,000 times the total energy consumption of humanity (as of 2010), a figure that is incredibly difficult to imagine. In comparison, the average annual electricity consumption for a three-person household in an independent residence is 4,000 kilowatt-hours, which represents only a small fraction of the solar energy entering the Earth's atmosphere.

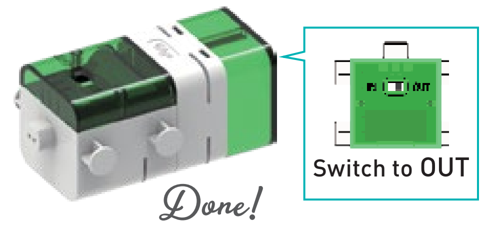
However, a significant portion of solar energy is lost in the atmosphere because the atmosphere "absorbs" or reflects solar energy. Nevertheless, the remaining solar energy is abundant and would theoretically be enough for humanity's electrical consumption.



EXPERIMENT 8: SUPERCAPACITOR FLASHLIGHT







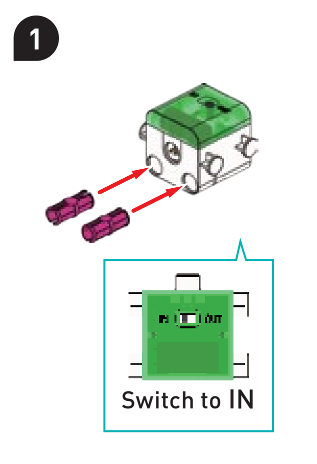
GO FURTHER!

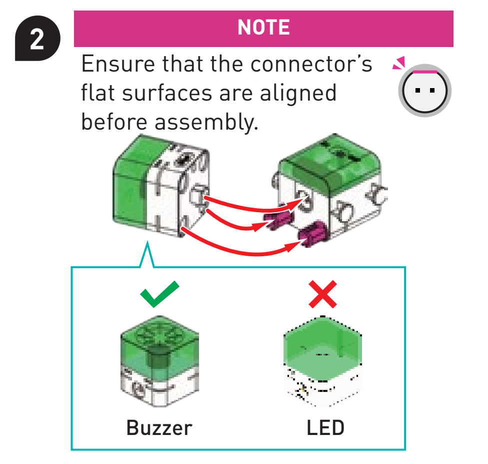
How many indicator lights need to be lit up for the LED to emit light?

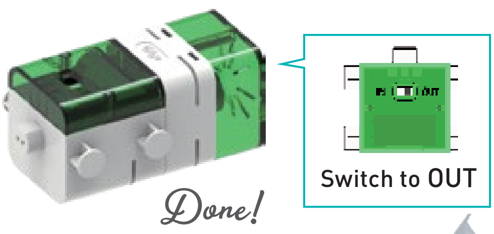
WHAT'S HAPPENING?

We've completed a flashlight model!
Switch the supercapacitor to discharging mode and try to power the LED light with the stored electricity from previous experiments.

EXPERIMENT 9: SUPERCAPACITOR BUZZER







GO FURTHER!

How many indicator lights need to be lit up for the buzzer to emit sound?

WHAT'S HAPPENING?

We've completed a buzzer model!
Switch the supercapacitor to discharging mode and try to power the buzzer with the stored electricity from previous experiments.

The Operating Principle of the Supercapacitor

With the supercapacitor, we can store green energy generated by solar and wind power and discharge it when needed. Do you know why the supercapacitor can both charge and discharge?

A supercapacitor consists of two carbon electrodes and an electrolyte, which can be a variety of liquid or solid materials. When we connect the wires to the positive and negative terminals of the supercapacitor, ions in the electrolyte move between the electrodes, generating a current. Compared to regular rechargeable batteries, supercapacitors have the advantages of fast charging and discharging speeds and long lifespans. They can be widely used in electric vehicles, flashlights, and other everyday items.

CHECK IT OUT

Transmission of Electricity

Once electricity is generated, it needs to be transmitted through the **electric grid** system. The electric grid functions like a highway for electrical current, bringing together all the electricity produced by major power plants and transporting it in the form of high-voltage power. The voltage in these primary transmission lines ranges from 220,000 to 380,000 volts (for comparison, your mobile phone typically operates at just 5 volts). When these primary lines reach substations, **transformers** are used to convert the high-voltage electricity into low-voltage electricity (see the image below) before it's distributed to homes and offices.

When an electric current flows through a metal wire conductor, the conductor experiences a repulsive or pushing effect. The current, much like friction between two objects, slows down due to this effect, leading to energy loss and causing the conductor to heat up. This phenomenon is known as **resistance.** Resistance is measured in ohms. When conducting current, our goal is to minimize the energy loss during transportation. You might have already thought of this method: the best way to keep resistance low is to make the voltage as high as possible! This is why transformers are used to increase the voltage when transmitting electricity.

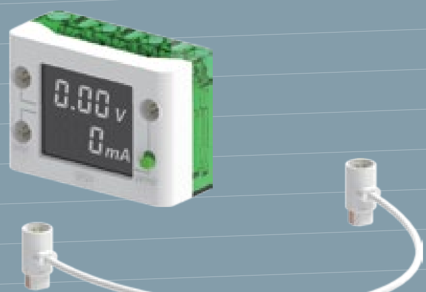
Supergrid: 220,000-380,000 voltage

High-voltage power grid: 110,000 voltage

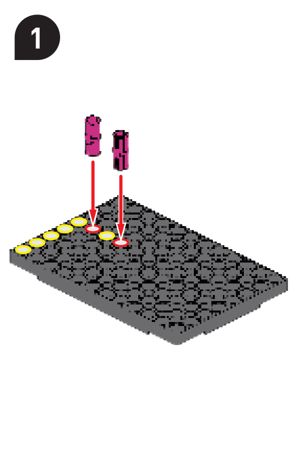
Medium-voltage power grid: 1,000-50,000 voltage

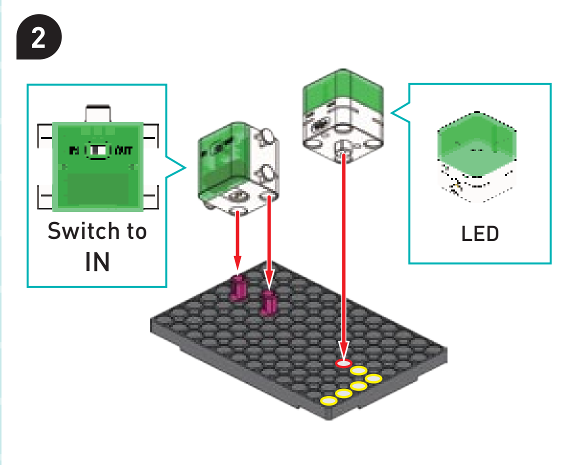
Low-voltage power grid (residential supply): 120-240 voltage

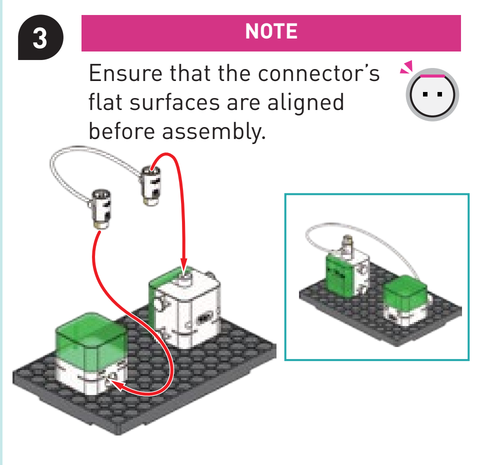
In this kit, we can use electrical wires (easy wire connectors) to transmit power. We can monitor current and voltage through the GEMS (green energy management system).

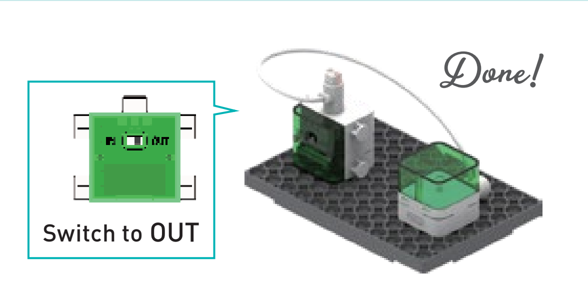


EXPERIMENT 10: WIRED LED LIGHT





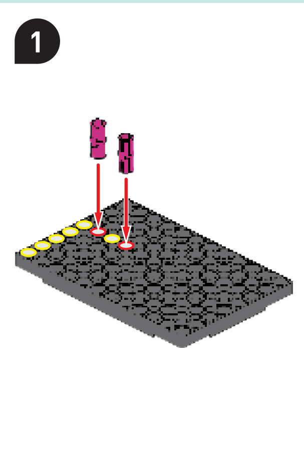


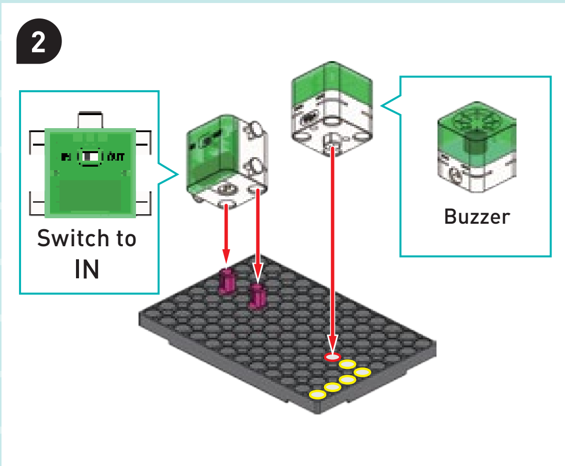


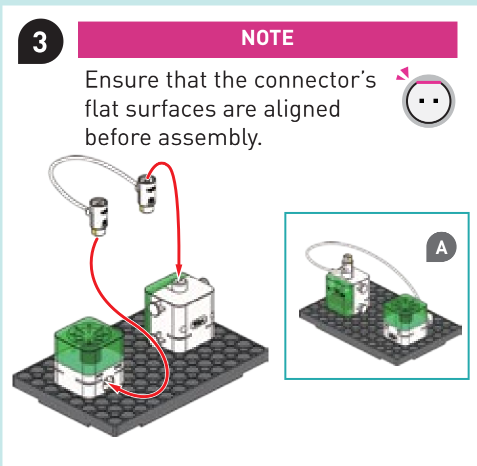
WHAT'S HAPPENING?

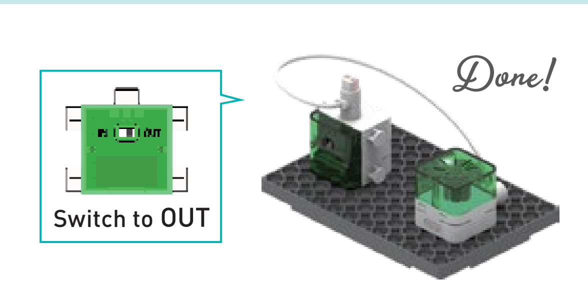
A water pump has two ends: one for suction and one for expulsion. Electrical current sources also have two ends, or **terminals.** At one, called the **positive pole,** they create a sort of electron vacuum. At the other end, the **negative pole,** they produce a sort of electron overload.
Current only flows when the poles, or terminals, are connected. Then, the electrons flow from the negative pole to the positive pole, and the force of their flow is capable of doing things like lighting an LED or powering a buzzer. If the circuit is broken at any point, the flow of current immediately stops.
Like typical electrical cords in your house, the easy wire connectors actually have two wires inside, and the terminals have two holes. This is because you need to create a complete loop — or **circuit** — in order for current to flow.

EXPERIMENT 11: WIRED BUZZER







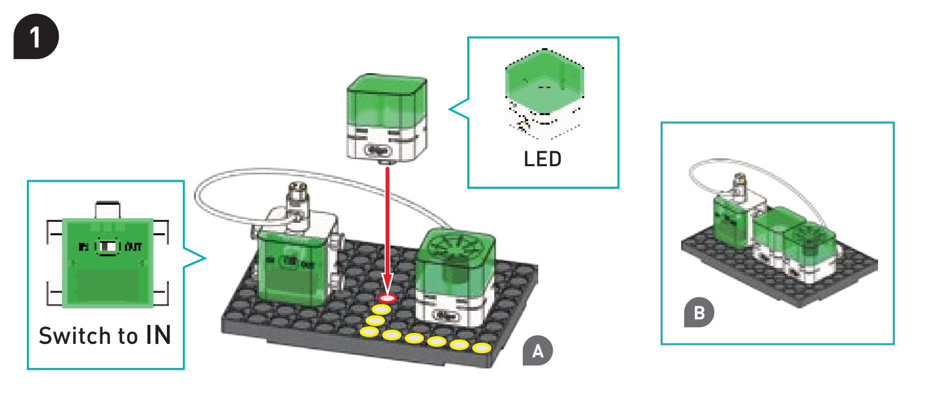


GO FURTHER!

1. Use the other parts in this kit to modify the model and make a desk lamp.
2. Use the other parts in this kit to modify the model and create a car that can emit sound.

EXPERIMENT 12: WIRED BUZZER+LED

1



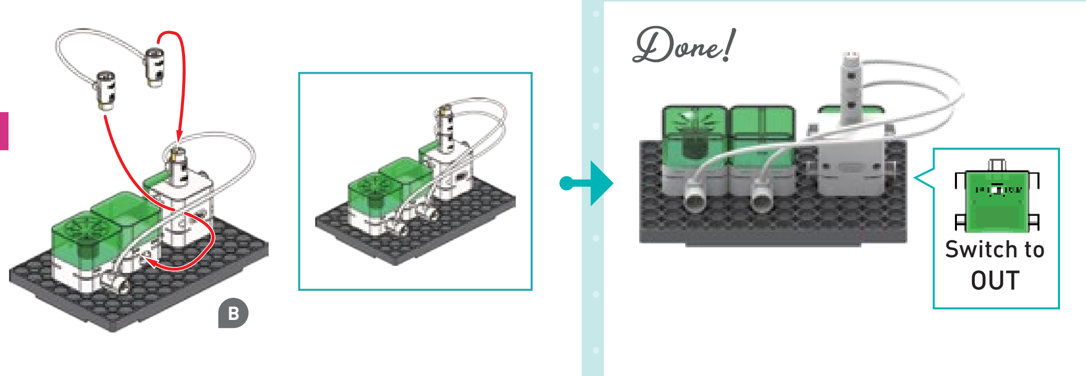
ADVANCED PRACTICE!

What other circuit configurations can you discover?

2-1

NOTE

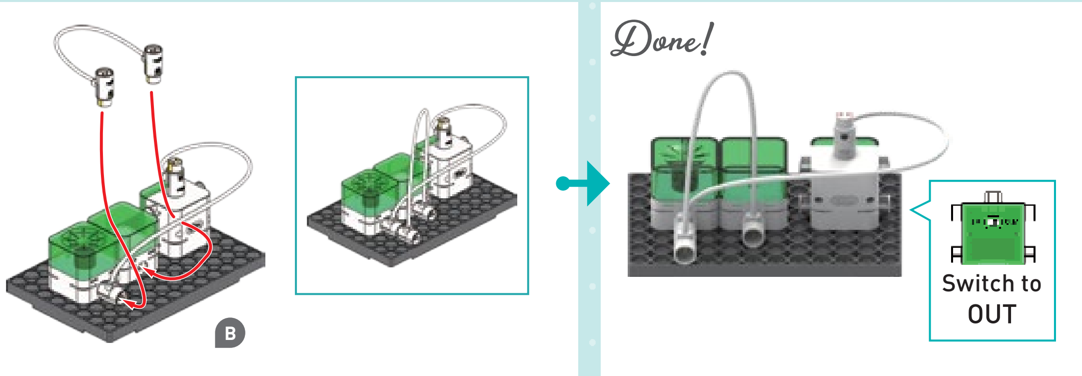
Ensure that the connector's flat surfaces are aligned before assembly.



2-2

NOTE

Ensure that the connector's flat surfaces are aligned before assembly.

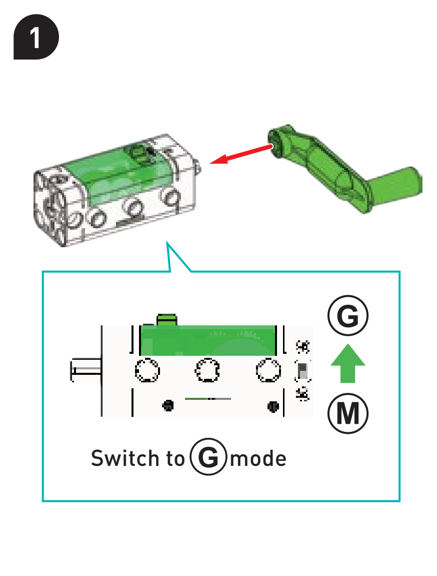


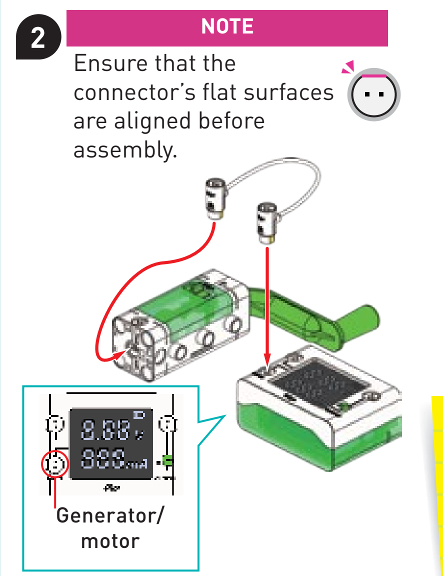
CHECK IT OUT

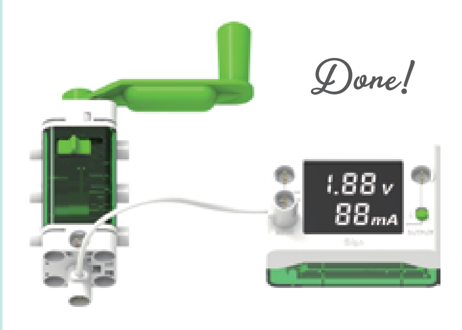
The operating principle of electrical wires

Electrical wires can transport electricity over long distances, connecting appliances to power sources, much like how water pipes distribute water to various locations. The primary material used in electric wires is copper, which is encased in a layer of plastic. Copper possesses low electrical resistance and excellent conductivity, thereby minimizing energy loss during the transmission of electric current. In the future, if we can find a superconductor with zero resistance and make it into wires, we can transmit the electricity generated by power plants without any energy loss!

EXPERIMENT 13: GEMS VOLTAGE METER I







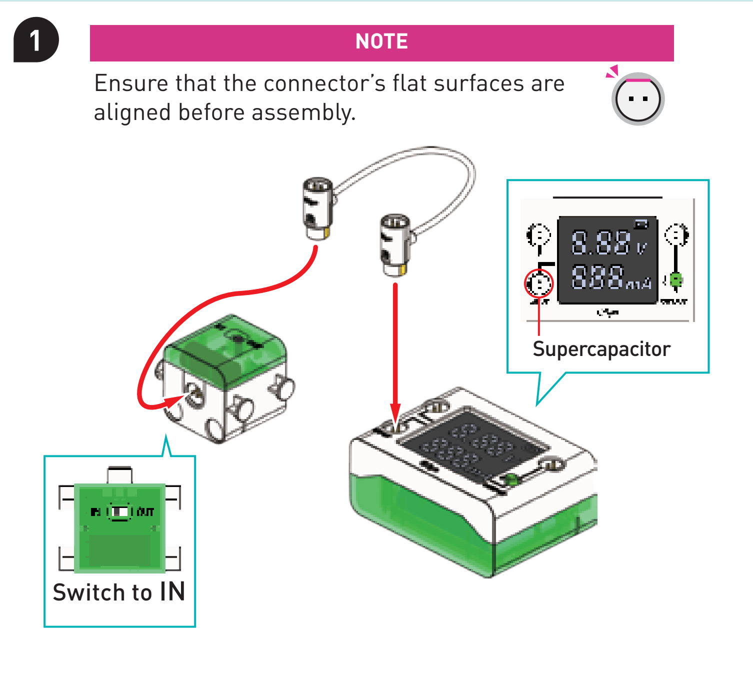
GO FURTHER!

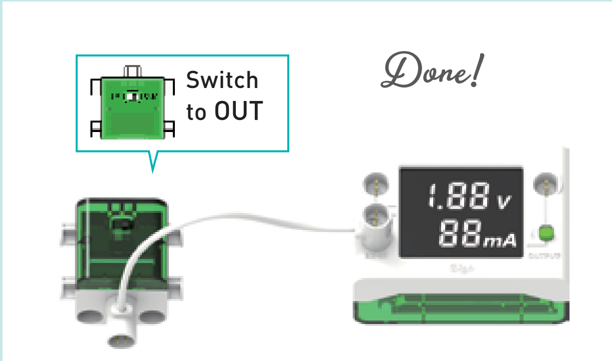
Rotate the hand crank while observing the voltage reading displayed on the GEMS. How is the speed that the crank is rotated related to the magnitude of the voltage?

WHAT'S HAPPENING?

Power on the GEMS and switch the generator/motor to generator mode. Use the GEMS to monitor the voltage generated by the hand crank power generation device. The voltage displays on the screen in real time.

EXPERIMENT 14: GEMS VOLTAGE METER II





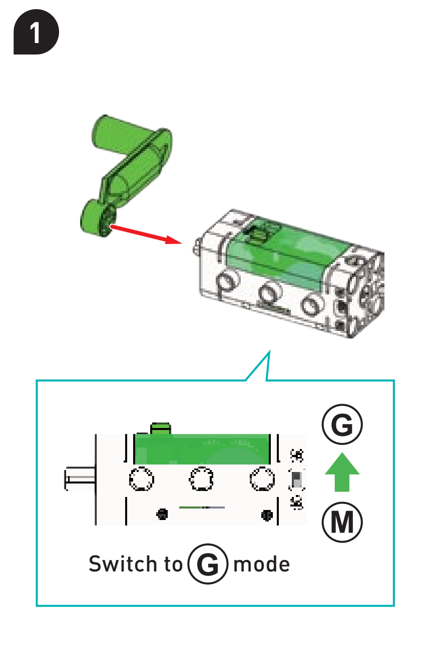
GO FURTHER!

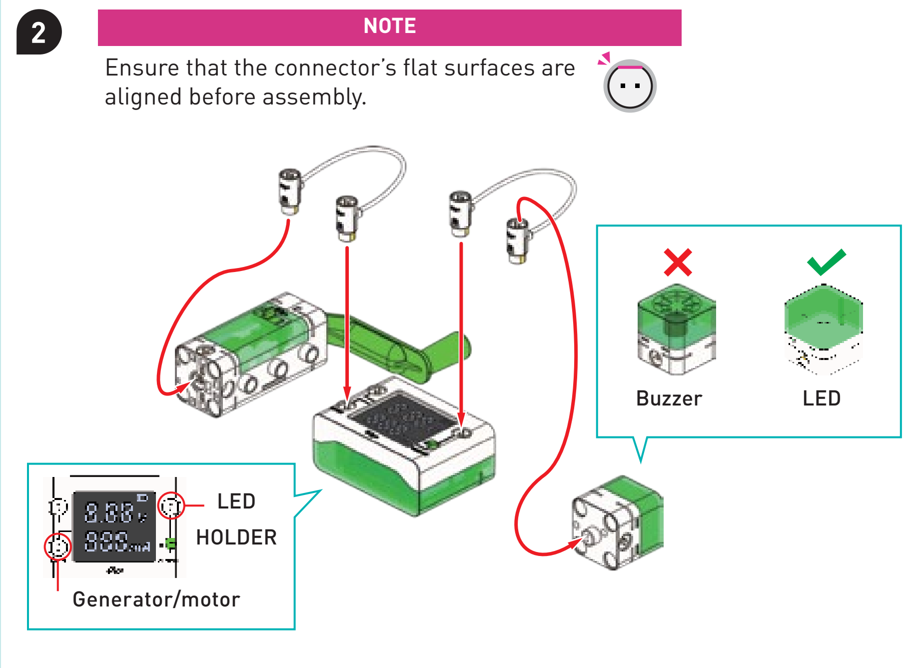
Try experimenting to observe the voltage generated by the supercapacitor at different battery levels using the GEMS. How do you think the voltage values will change over time?

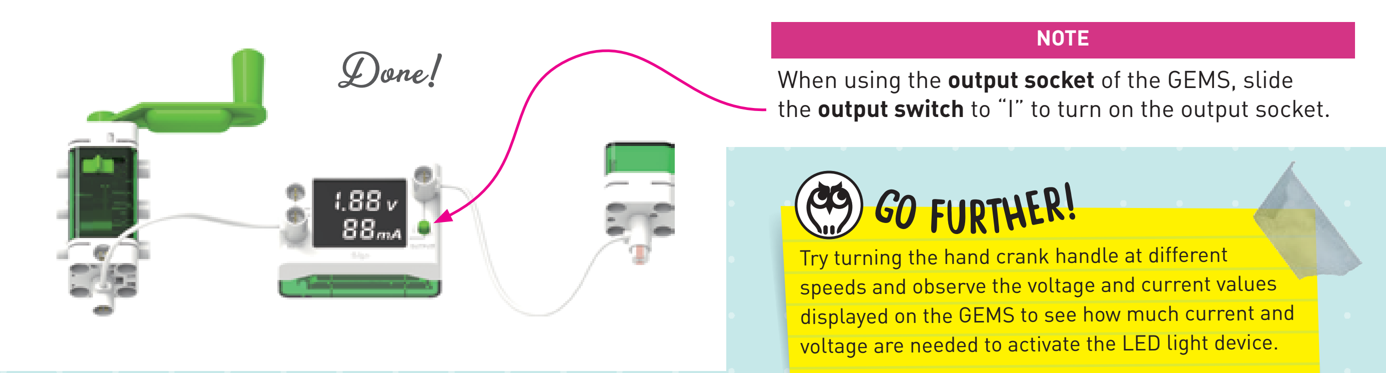
WHAT'S HAPPENING?

Power on the GEMS and switch the supercapacitor to discharging mode. Observe the voltage reading displayed on the GEMS.

EXPERIMENT 15: VOLTAGE AND CURRENT I







GO FURTHER!

Try turning the hand crank handle at different speeds and observe the voltage and current values displayed on the GEMS to see how much current and voltage are needed to activate the LED light device.

WHAT'S HAPPENING?

We've connected the hand crank power generation device, GEMS, and LED light together using the easy wire connectors! Turn on the power switch and output switch of the GEMS, and switch the generator/motor to generator mode. Use the GEMS to monitor the voltage and current generated by the hand crank power generation device.

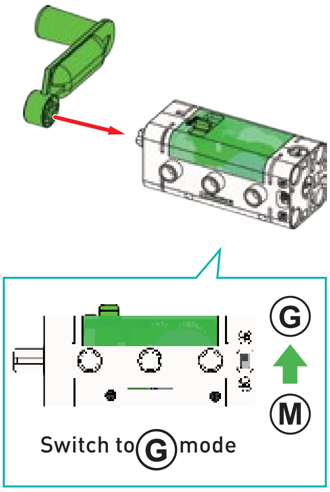
CHECK IT OUT

Current vs. Voltage

The driving force for electrical current is known as **electric voltage,** which is measured in units called **volts.** In our water-pipe example, voltage would correspond to the water pressure produced by a water pump.

It's important to distinguish carefully between voltage and **current,** which is measured in **amperes, or amps** for short. Available voltage doesn't mean that current is actually flowing — just as water won't flow from a closed water tap just because there is pressure in the water line. On the other hand, high pressure can push more water through the tap per second than low pressure can. A high electric voltage, likewise, can make a current flow with more strength than low voltage.

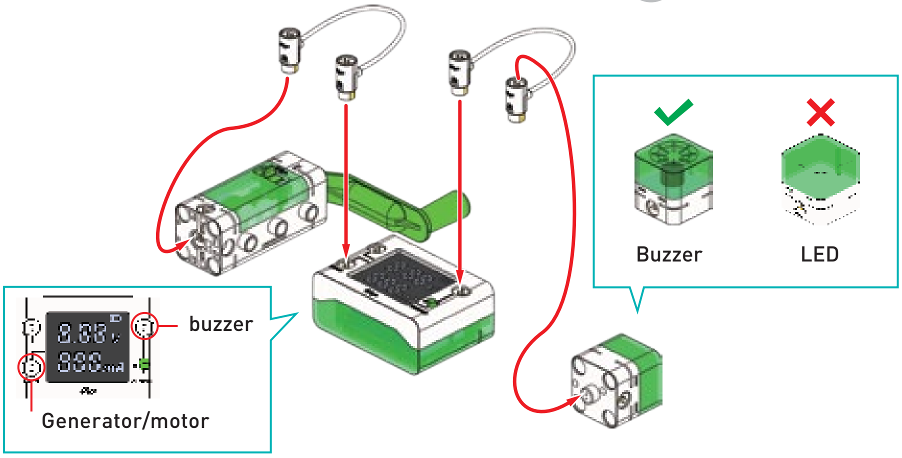
1

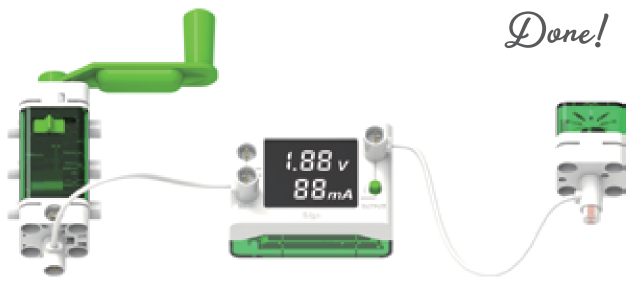


2

NOTE

Ensure that the connector's flat surfaces are aligned before assembly.





WHAT'S HAPPENING?

We've connected the hand crank power generation device, GEMS, and buzzer together using the easy wire connectors! Turn on the power switch and output switch of the GEMS, and switch the generator/motor to generator mode. Use the GEMS to monitor the voltage and current generated by the hand crank power generation device.

CHECK IT OUT

Calculating Electrical Power

The formula **"P = IV"** represents the relationship between **power (P), voltage (V),** and **current (I)** in an electrical circuit, and it's a fundamental formula in electrical engineering.

Electrical power (P) is typically measured in **watts (W),** and indicates energy consumption or generation associated with electronic devices.

This formula signifies that power is equal to voltage multiplied by current. It's used to calculate the power in a circuit, which is the rate of energy transfer.

Electric power has many applications in daily life, such as:

Household appliances:
Electric power can indicate the power consumption of household appliances, such as light bulbs, refrigerators, computers, etc. Understanding the power consumption of these devices helps manage electricity usage and control electricity bills.

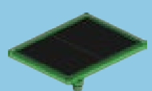
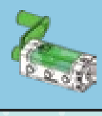
Power tools:
Electric power can be used to indicate the power of various power tools, such as drills, saws, vacuum cleaners, etc. This helps in selecting the appropriate tool to meet different job requirements.

Electric vehicles:
The horsepower of electric vehicles is typically described in terms of electric power, representing the power output of the electric motor. Knowing the power of electric vehicles can help people choose the model that suits their needs.

EXPERIMENT 17: RECORDING CURRENT AND VOLTAGE

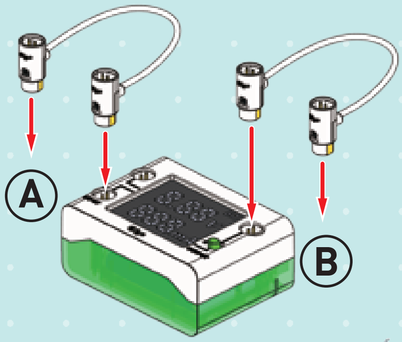
Try experimenting by connecting components of different power generation methods (A) and electrical devices (B) to the GEMS, and make sure the power switch and output switch of the GEMS are turned on.

Record the voltage and current when they are operating in the table below.

A \ B			 35x	 IN
	V= A=	V= A=	V= A=	V= A=
 OUT	V= A=	V= A=	V= A=	V= A=
 35x	V= A=	V= A=	V= A=	V= A=
 70x	V= A=	V= A=	V= A=	V= A=

Physical Quantity/Unit

Physical Quantity	Power	Current	Voltage
Symbol	P	I	V
Unit of Measurement	Watt	Ampere	Volt
Unit Abbreviation	W	A	V



GO FURTHER!

Take a look at the table after the experiments. Can you find the combination that produces the highest power through the formula (P = IV)?

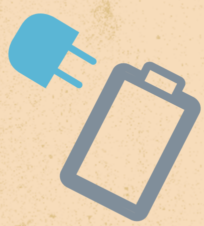
CHECK IT OUT

THE USE AND STORAGE OF ELECTRICITY

When electricity is delivered to various households and offices, it can be used directly through outlets. Some devices, however, require the use of **batteries** that are powered by stored electrical energy. Batteries have advantages such as small size, portability, and the ability to operate without direct access to outlets. Some batteries can also be recharged and discharged repeatedly. Here are examples of electricity's widespread applications in various fields:

Household Electricity: Used for lighting, heating, and household appliances such as refrigerators, air conditioners, and washing machines.

Industrial and Manufacturing: Electricity is essential for operating machinery, driving production lines, and running equipment in various industries.



Transportation: Electric vehicles, public buses, and electric trains rely on electricity as a clean and efficient power source.

Electronics: Electricity powers a wide range of electronic devices, including computers, mobile phones, televisions, and electronic games.

In experiment 17, we calculated the power generated, but if we want to discuss consumption over a period of time, we need to use **kilowatt-hours (kWh)** as the unit. The calculation is as follows:

$$\text{kWh} = \text{Power (kW)} \times \text{Time (h)}$$

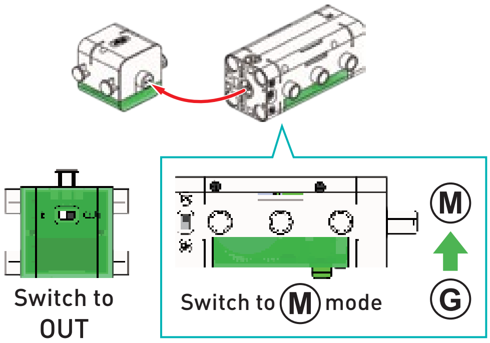
Here, power is measured in kW (1 kW is equivalent to one thousand watts) and time is measured in hours. One kilowatt-hour represents the consumption of one kilowatt of power over one hour, also known as one unit of electrical energy (kWh). In other words, one unit of electrical energy represents the energy consumed by continuously using one kilowatt of power for one hour. This is the basic unit of electricity billing and a common indicator of power consumption in our daily lives. You can check your electricity bill at home to see how many units of electrical energy your house consumes in a month!

EXPERIMENT 18: ELECTRIC VEHICLE

1

NOTE

Ensure that the connector's flat surfaces are aligned before assembly.



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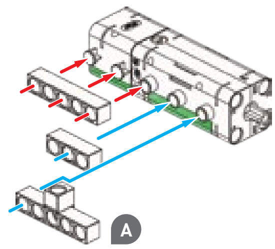

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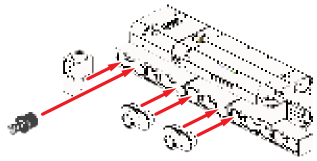

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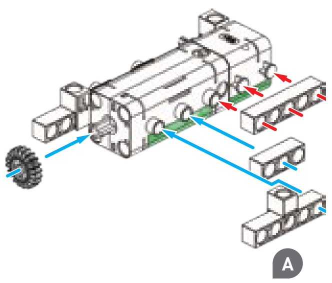

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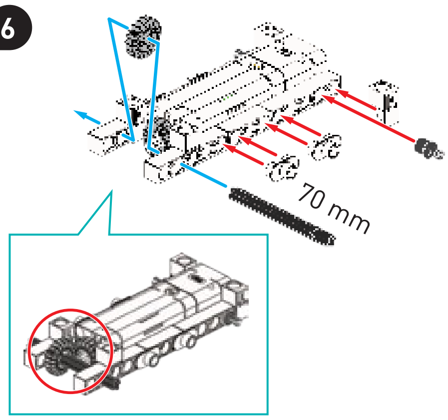

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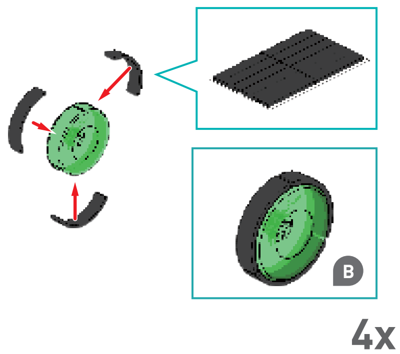

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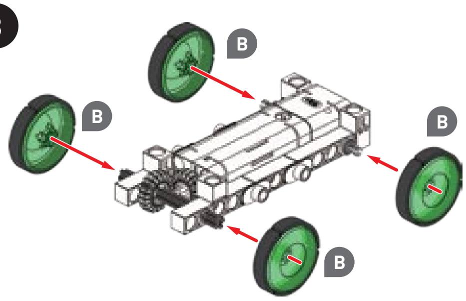

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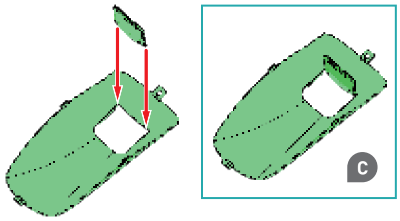

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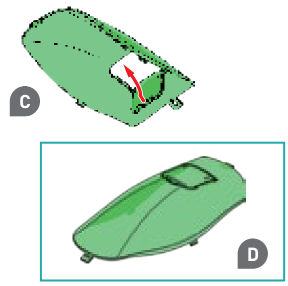

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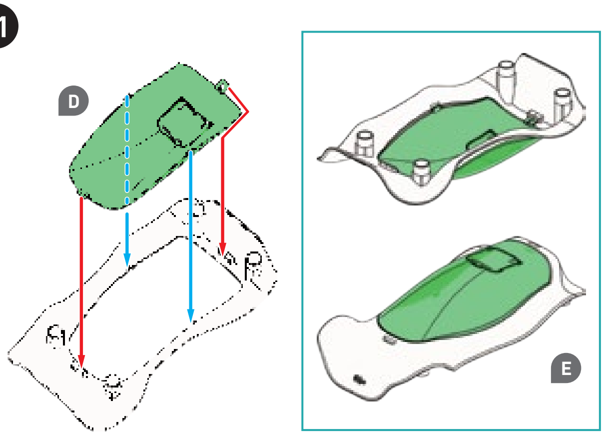

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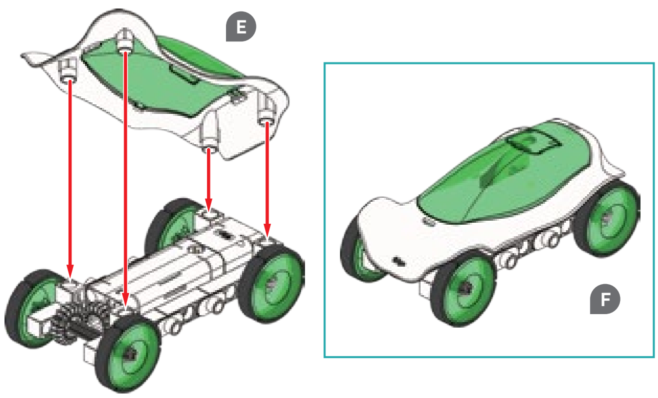
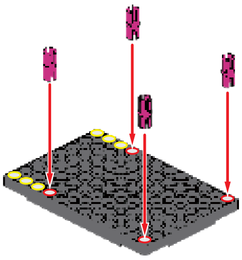


EXPERIMENT 19: EV CHARGING STATION

1



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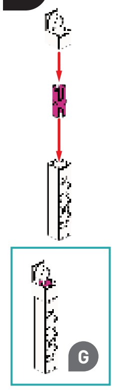
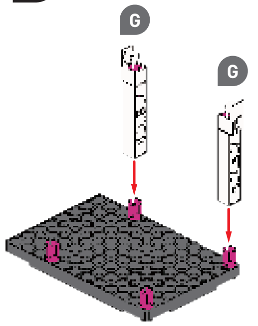


4x

3



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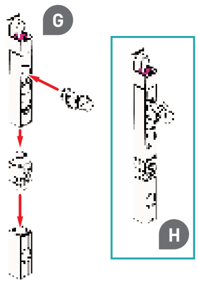
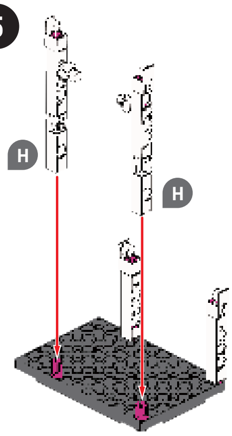


2x

5



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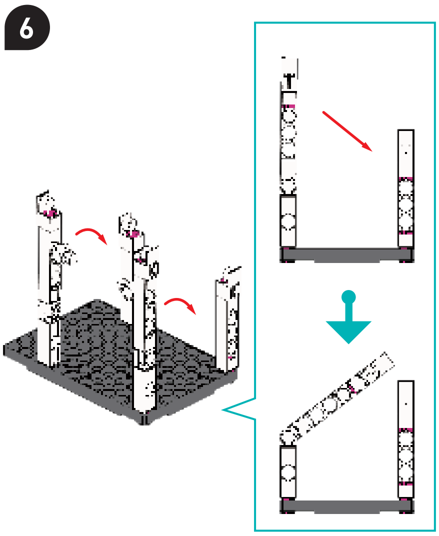

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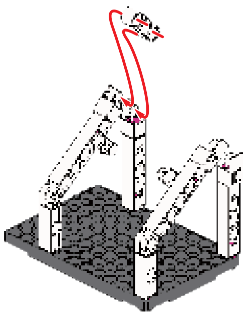

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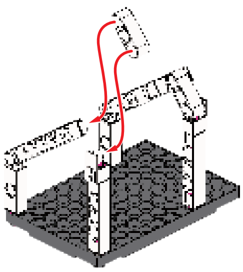

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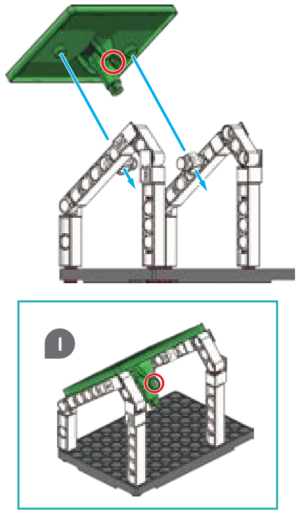
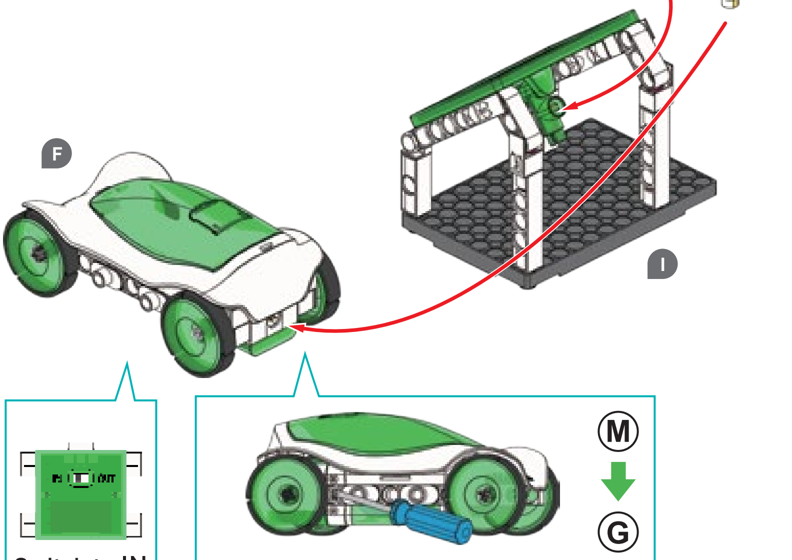


10

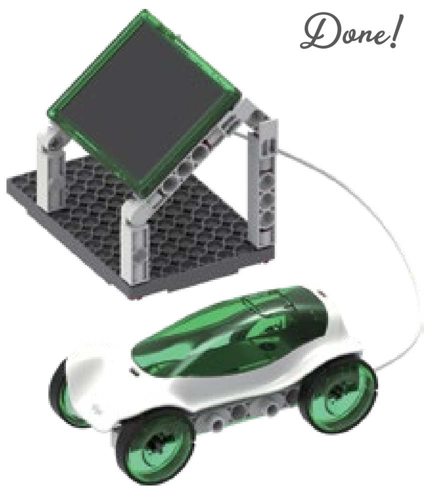
NOTE

Ensure that the connector's flat surfaces are aligned before assembly.



Switch to IN

Use a small screwdriver to switch to G mode.



Done!

GO FURTHER!

How much time does it take to fully charge the electric vehicle under different lighting conditions?

WHAT'S HAPPENING?

We've completed an electric car and the charging station!
Before charging, please ensure that the supercapacitor is switched to charging mode, and the generator/motor is switched to generator mode. When the 60-watt halogen lamp or sunlight shines on the 4.5V solar panel, the electric vehicle charging station can then transmit the generated power to the supercapacitor via the easy wire connector, charging the electric vehicle.

An electric car at the charging station

CHECK IT OUT

Cars that don't need gasoline — Electric Vehicles (EVs)

Electric Vehicles (EVs) are a type of transportation that is powered by electricity, typically using batteries to store electrical energy. The operation of electric vehicles differs from traditional internal combustion engine vehicles as they use electric motors to generate power instead of burning fossil fuels. Electric vehicles have many advantages, such as lower environmental impact, high energy conversion efficiency, and no noise pollution during operation.

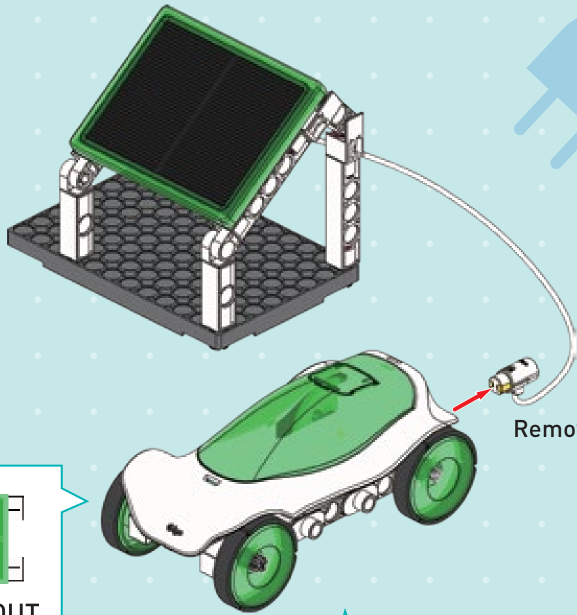
While electric vehicles have clear environmental benefits, they also face challenges such as limited driving range, the need for more widespread charging infrastructure, and battery costs. Electric cars are also only truly emission-free if the electricity used to charge them is generated from renewable energies. If oil or gas is burned to generate the electricity, they are still responsible for carbon dioxide emissions — from the power plant, rather than the car.

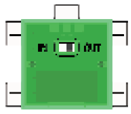
With advancing technology and increased investment in green energy, electric vehicles are expected to become a more widely adopted mode of transportation in the future, reducing dependence on finite fossil fuels and protecting the environment.

EXPERIMENT 20: CHANGING ELECTRIC VEHICLE GEAR RATIO

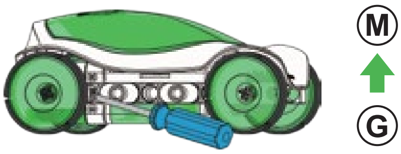
First, switch the supercapacitor to discharge mode and switch the generator/motor to motor mode. Use the stored power inside the supercapacitor to make the electric vehicle move forward. Before conducting the experiment, ensure that the supercapacitor is fully charged (with three indicator lights lit up).
Now try experimenting by switching the gear ratio of the generator/motor to 35X and 70X.

How do think these two gear ratios will impact the electric vehicle's performance?





Switch to OUT

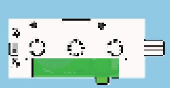


Use a small screwdriver to switch to (M) mode.

CHECK IT OUT

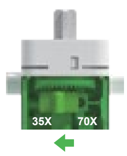
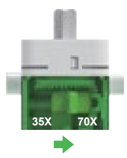
The relationship between gear ratios in motor mode and generator mode

In experiment 3, we noted that using a 70X gear ratio requires more force to rotate the handle but produces higher voltage, resulting in a brighter flashlight. Conversely, using a 35X gear ratio allows for easier rotation of the handle but yields lower voltage, resulting in a dimmer flashlight. However, this is reversed in the operation of the electric vehicle. The reason is that the gear transmission direction in motor mode and generator mode is opposite, leading to different effects of gear ratio settings in these modes. You can refer to the table below to confirm the effects of gear ratios in different situations. For example, both the 70X gear ratio in generator mode and the 35X gear ratio in motor mode increase the speed of the generator/motor but require more force.

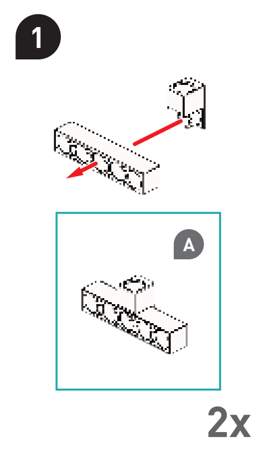
Mode \ Times	35X	70X
Output ← Input  GENERATOR	The input end can be rotated with less force. Less voltage is generated.	The input end requires a greater force to rotate. More voltage is generated.
Input → Output  MOTOR	The axle rotates at a faster speed but with a smaller torque.	The axle rotates at a slower speed but with a larger torque.

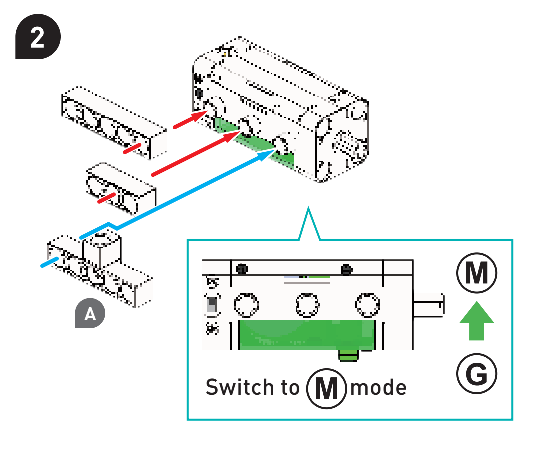
WHAT'S HAPPENING?

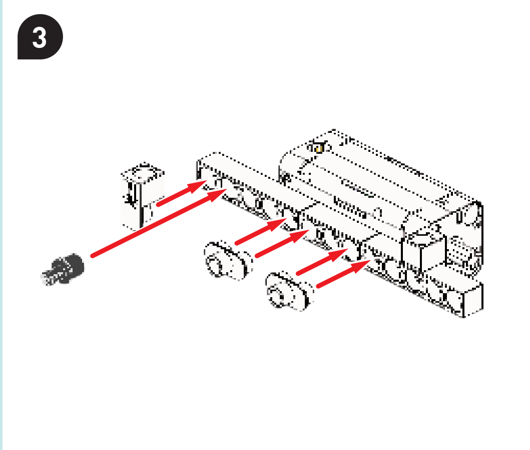
When we switch the generator/motor to 35X, the torque of the electric vehicle will be smaller, but it will have a faster speed, suitable for racing. When we switch it to 70X, the speed of the electric vehicle will be slower, but the torque will be larger, suitable for climbing hills or carrying heavy loads. You can adjust the gear ratio based on different situations!

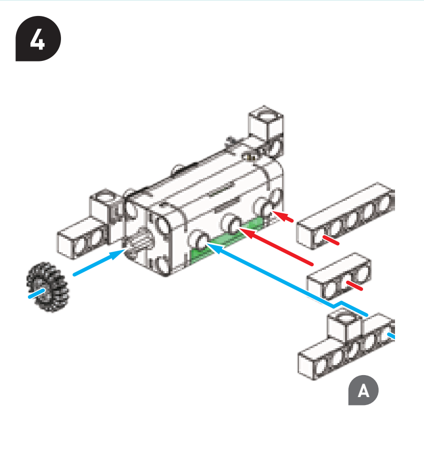
Mode	Diagram	Effect
35X		The electric car has high speed but low torque.
70X		The electric car has low speed but high torque.

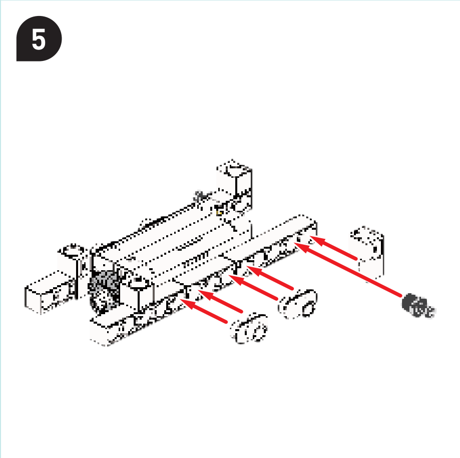
EXPERIMENT 21: SOLAR VEHICLE

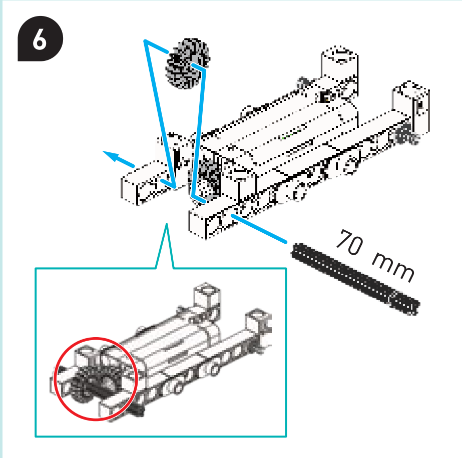


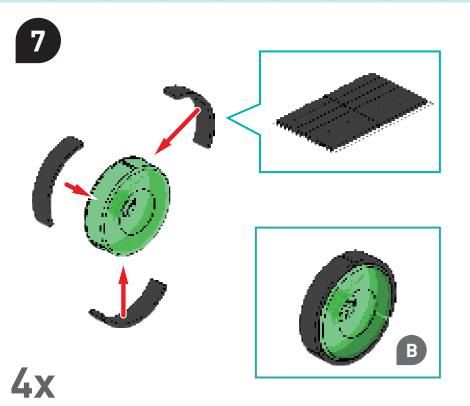


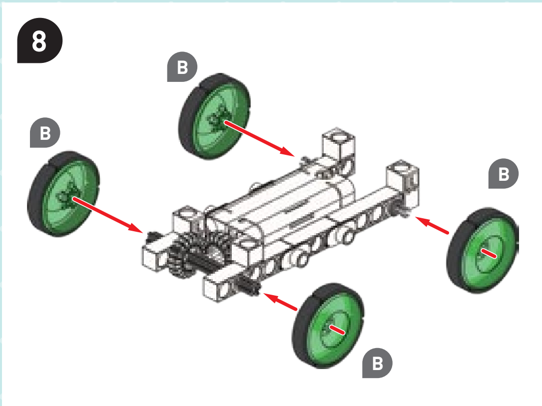


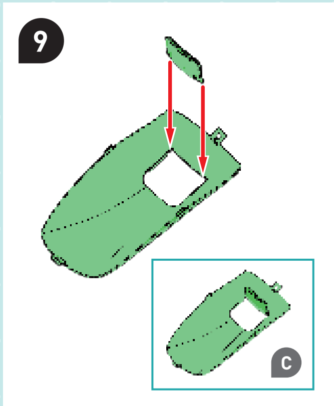


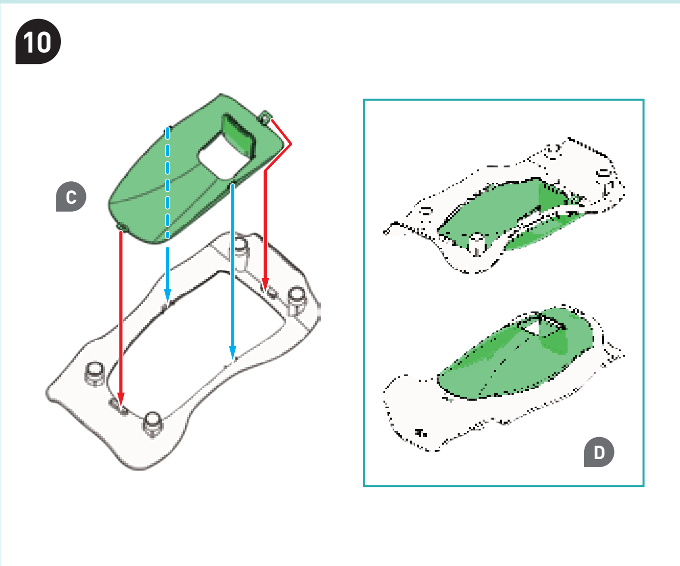


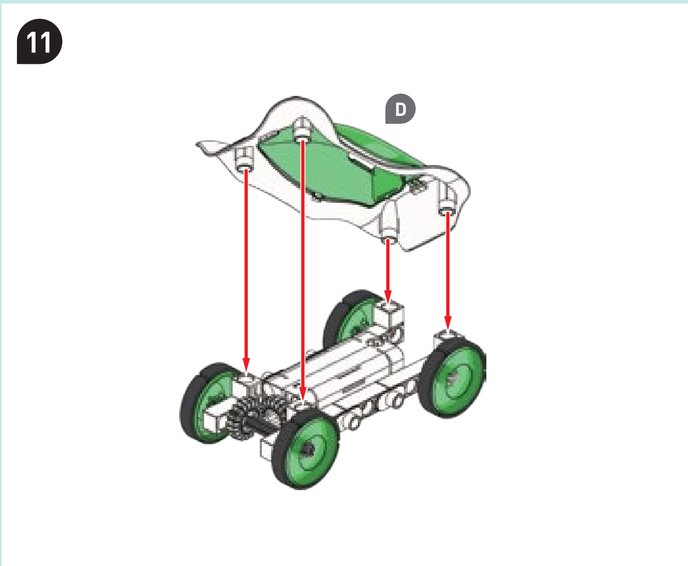








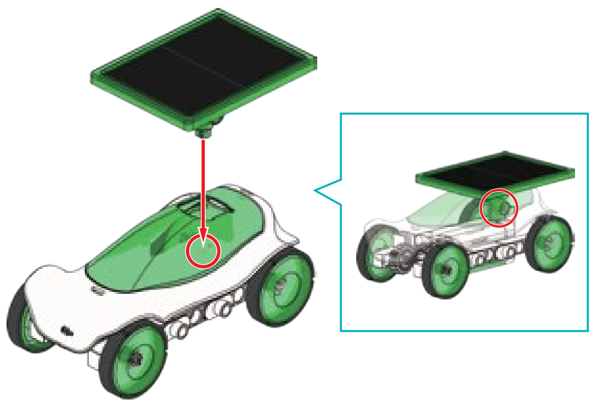




12

NOTE

Ensure that the connector's flat surfaces are aligned before assembly.



Done!

WHAT'S HAPPENING?

We have completed a solar-powered vehicle!
Before conducting the experiment, please switch the generator/motor to motor mode. When sunlight or a 60-watt halogen lamp shines on the 4.5V solar panel, the solar-powered vehicle can be successfully activated.

GO FURTHER!

Try to cover half of the 4.5V solar panel with a piece of black paper. Can the solar-powered vehicle still move?

CHECK IT OUT

Solar Vehicle Racing Competition

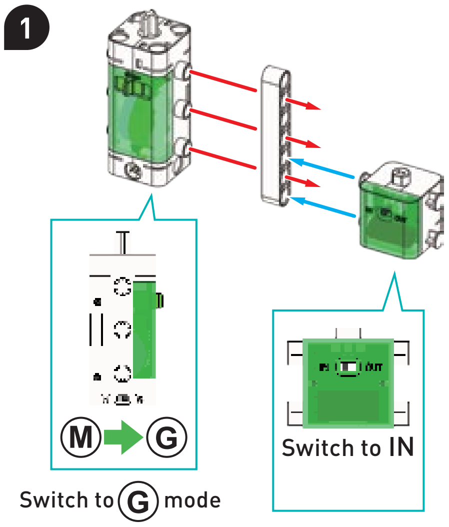
Solar vehicles have advantages such as environmental friendliness, quiet operation, and durability. In Australia, there is even a famous solar car racing event called the "World Solar Challenge". This is an international competition that attracts participators from universities, research institutions, and companies worldwide.

The goal of this challenge is to design, manufacture, and drive solar-powered cars to complete a 3,000-kilometer journey across the Australian outback. Participating vehicles must rely on solar power during the day and stored energy at night. The route of the challenge spans most of Australia, from Darwin to Adelaide.

The challenge showcases the potential of solar energy in the field of transportation and promotes the development of renewable technology and innovation. Teams face extreme weather conditions and terrain challenges, making the race more challenging and driving the development of more advanced and efficient technologies.

EXPERIMENT 22: MONITORING WIND CHARGING

1



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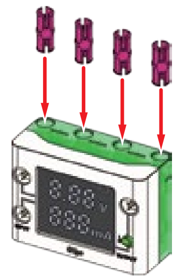

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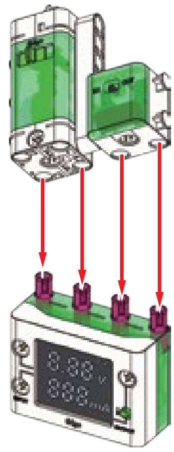

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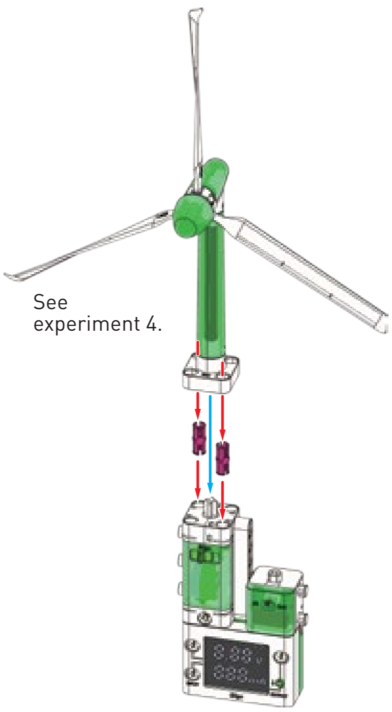

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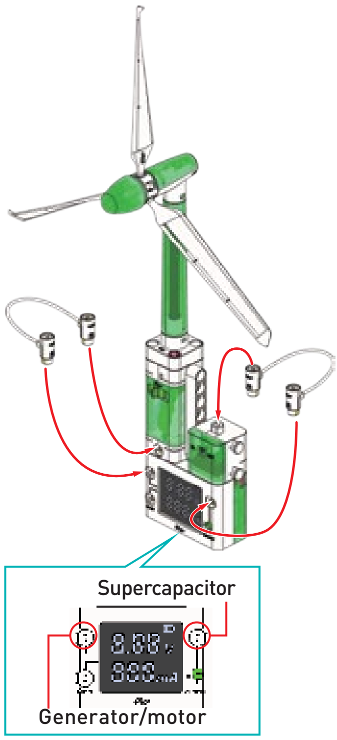
NOTE

Ensure that the connector's flat surfaces are aligned before assembly.



Done!

GO FURTHER!

How much time does it take to fully charge the supercapacitor?

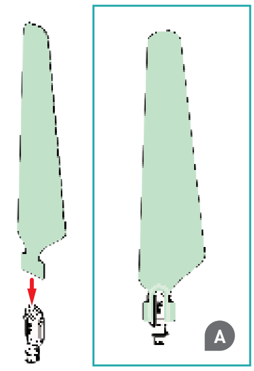
WHAT'S HAPPENING?

We have completed a wind power charging monitoring device!

Try experimenting by switching the supercapacitor to charging mode and the generator/motor to generator mode. Finally, turn on the power switch and output terminal switch of the GEMS. Use wind power to charge the supercapacitor and monitor the generated voltage and current on the screen of the GEMS.

EXPERIMENT 23: DIY BLADES

1



Design your own wind turbine blades or use the template.

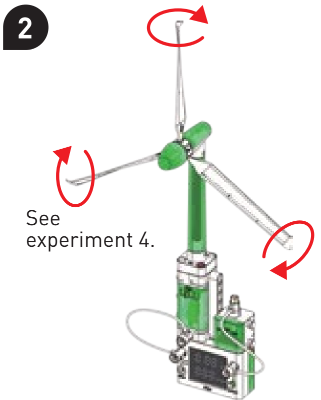
You will need:

Scissors
A clean plastic bottle
Printed template or your own paper/cardboard blades

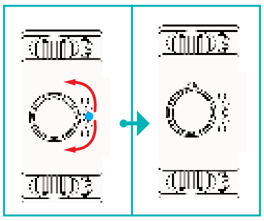
Scan the QR code to download a template.

6x

2

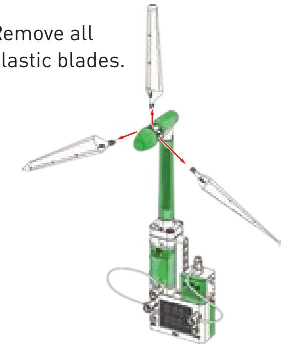


See experiment 4.



Rotate the three blades approximately 90 degrees.

Remove all plastic blades.



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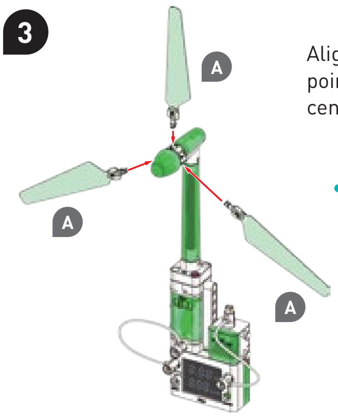
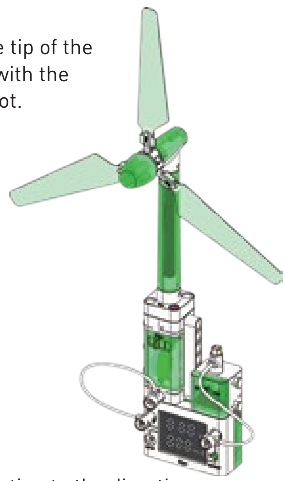
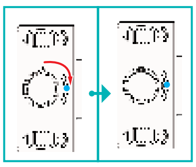


Align the tip of the pointer with the center dot.



You can align with different dots to adjust the blade angle.

Note that all blade pointers need to be aligned with the same dot.



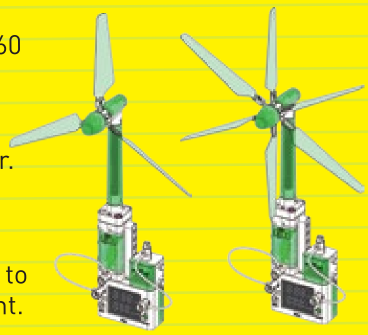
Pay attention to the direction of the blades during assembly. Push them to the bottom and then rotate.

Done!

GO FURTHER!

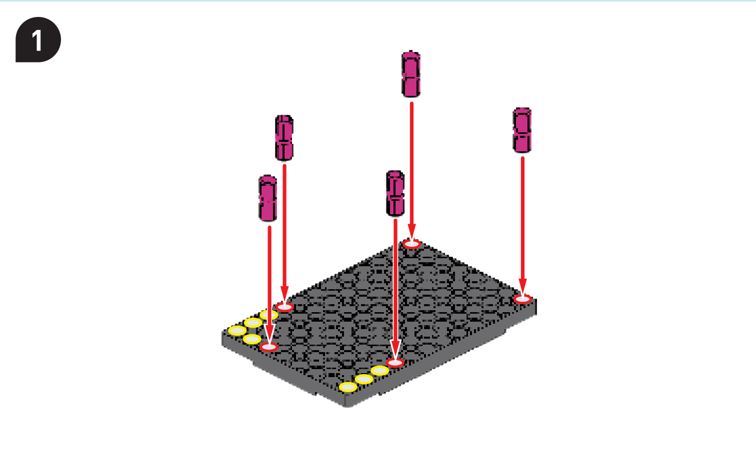
Use your self-made blades to conduct the following experiments:

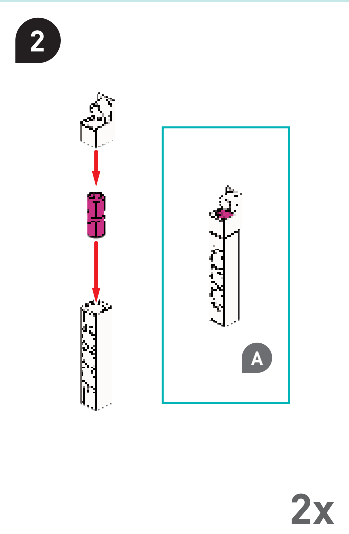
1. Try adjusting all the blades to different angles, such as 0 degrees, 30 degrees, and 60 degrees. Experiment to see which angle allows the blades to produce the highest voltage or current.
2. Try making blades in different shapes, such as triangular, diamond, and rectangular. Experiment to see which shape allows the blades to produce the highest voltage or current.
3. Try changing the number of blades, such as three, four, and six blades. Experiment to see which number of blades allows the fan to produce the highest voltage or current.

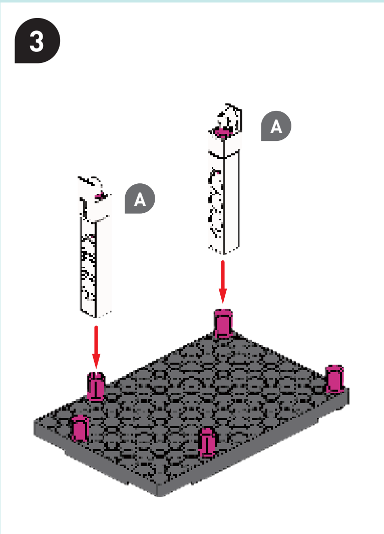


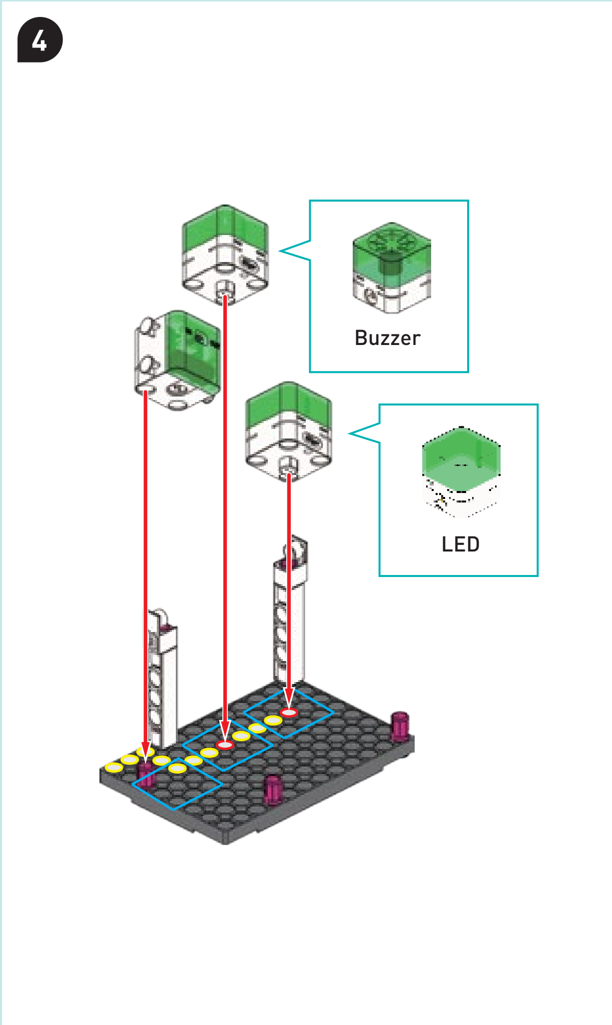
EXPERIMENT 24: HYBRID POWER PLANT

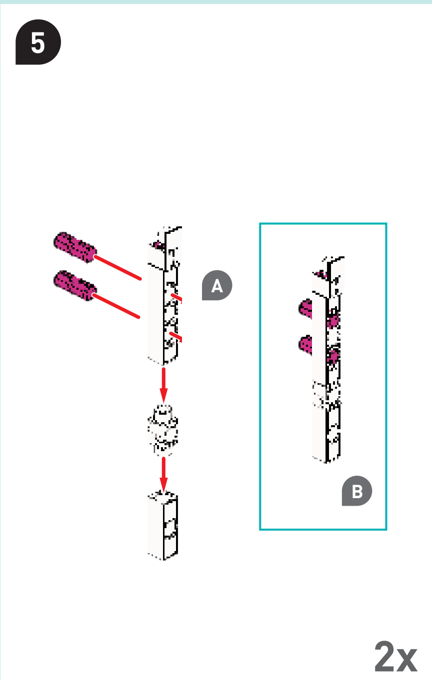
It's time to put together everything you've learned and build your very own renewable energy power plant!

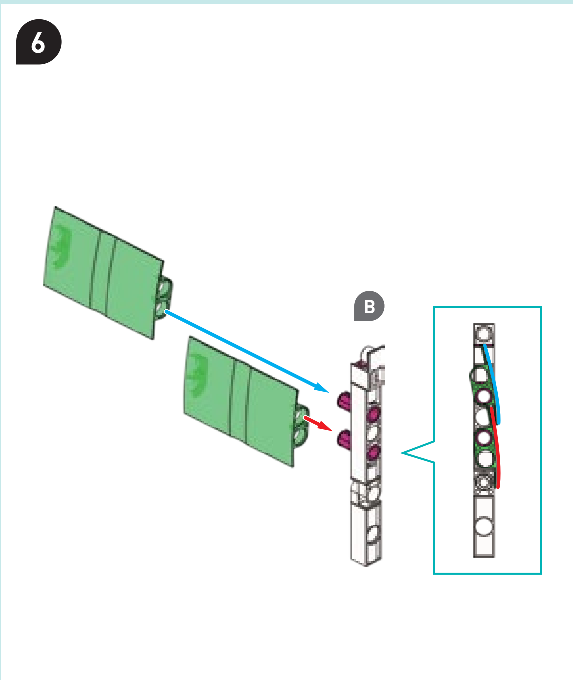


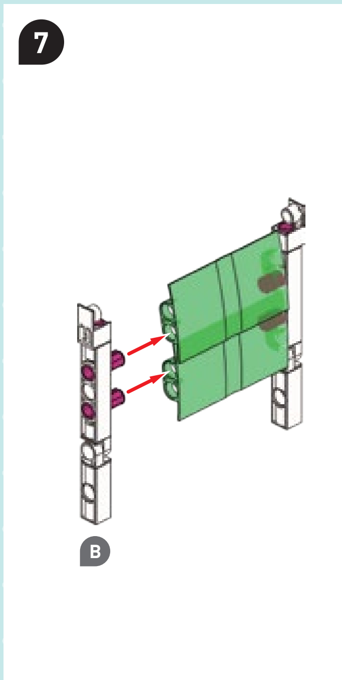












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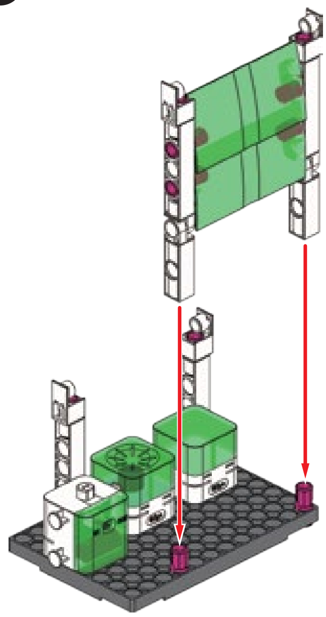

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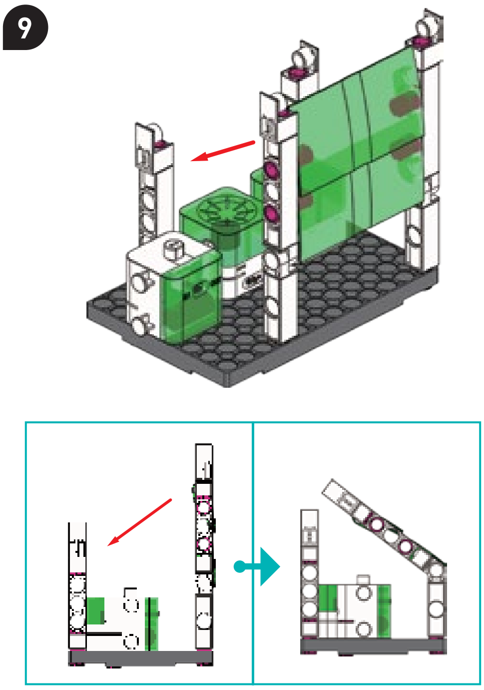

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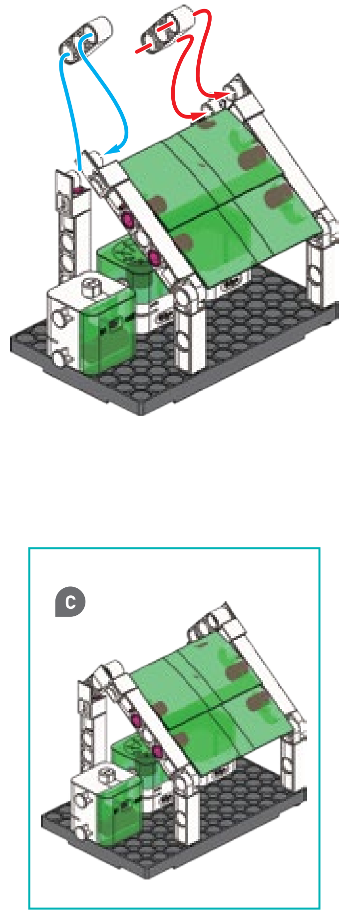

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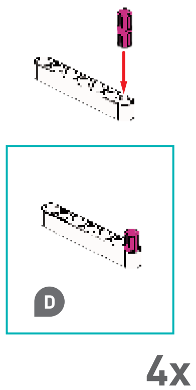

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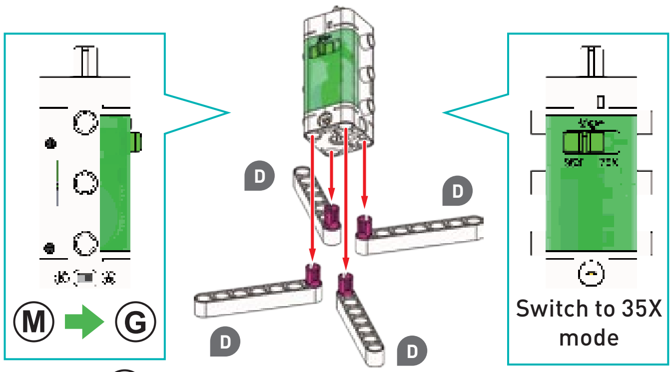
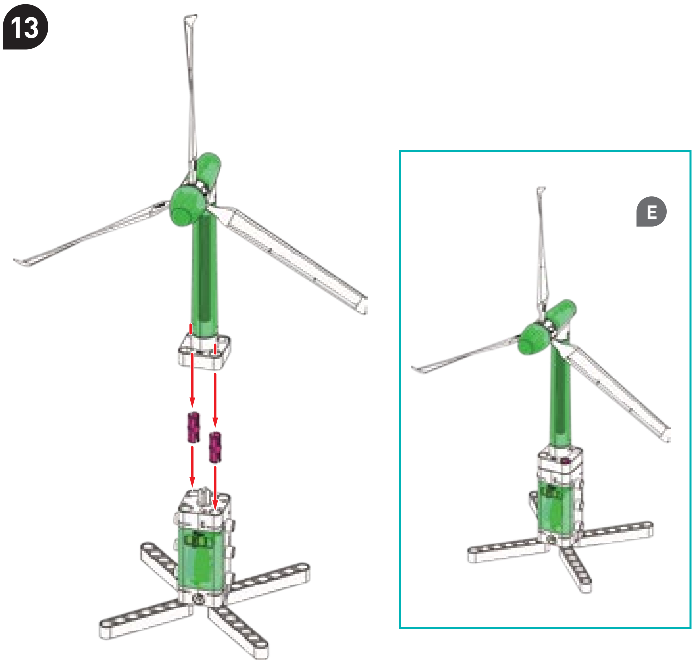


Switch to G mode

13



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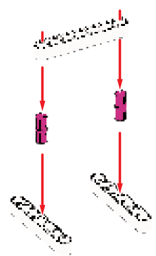

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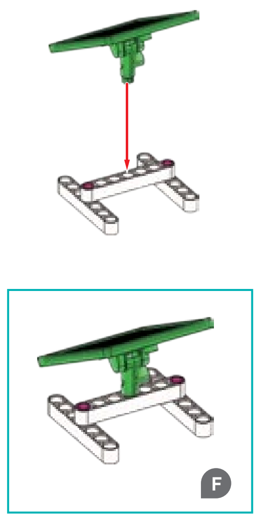
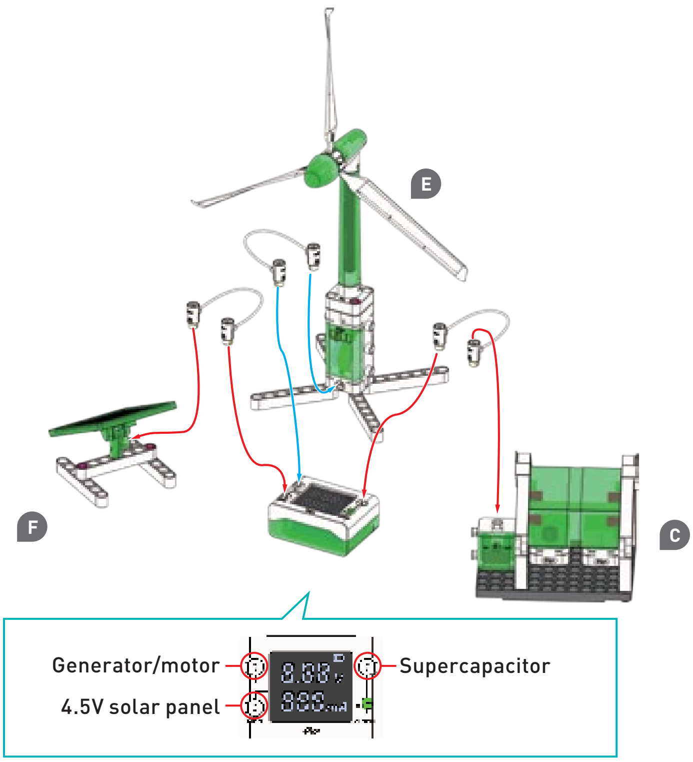


16

NOTE

Ensure that the connector's flat surfaces are aligned before assembly.



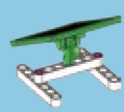
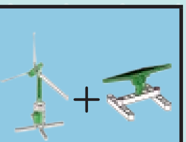
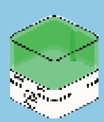
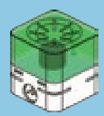
Done!

WHAT'S HAPPENING?

We have completed a hybrid power supply device! Try experimenting by switching the supercapacitor to charging mode and the generator/motor to generator mode. And then switch on the power and output switches of the GEMS. You can use two different power generation methods and monitor the generated voltage and current on the screen of the GEMS. Apply the generated electricity to the LED light, buzzer, or supercapacitor.

GO FURTHER!

Use different methods of power generation to activate various electrical devices. Record your observations in the table below. Note changes such as the brightness of the LED module, the volume of the buzzer module, the charging speed of the supercapacitor, and the value changes on the GEMS, and so on.

Type of power / Device			
			
			
			

CHECK IT OUT

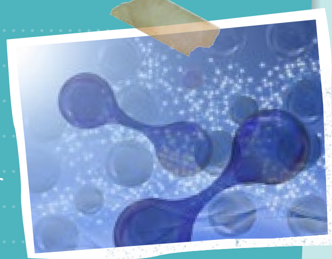
Renewable Energy

In this kit, we use both wind and solar energy as **renewable energy sources** for power generation. Besides the renewable energy sources introduced in this kit, there are other renewable energy sources on Earth, such as biomass energy, geothermal energy, hydrogen energy, and more.

Biomass Energy: Burning biomass, such as plants and wood, releases a significant amount of energy. By continuously planting new vegetation and trees, biomass energy can sustainably operate. Additionally, biogas plants (which ferment organic waste) can produce combustible gas with the help of bacteria, decomposing materials like corn stalks into gas suitable for power generation. However, this type of energy source still generates greenhouse gas emissions.

Geothermal Energy: The Earth's interior is extremely hot (about 5,000 °C), generating vast energy reserves below the surface that can be converted into usable energy for humans. To harness this, people dig deep holes into the ground and flood them with water. The heated water then boils due to geothermal heat, forming steam that rises and powers thermal power plants. Geothermal energy can also be used in homes through heating equipment called heat pumps, providing ample energy.

Hydrogen Energy: Hydrogen energy generation involves using hydrogen gas as a source of energy, harnessing the chemical reaction between hydrogen and oxygen to produce electricity, with water being the only byproduct, making it environmentally friendly. However, one challenge faced by hydrogen energy generation is the production and storage of hydrogen gas. Currently, the most common method of hydrogen production is through water electrolysis, which consumes a considerable amount of electricity. Another challenge is establishing a comprehensive hydrogen energy infrastructure, including facilities for production, storage, transportation, and utilization of hydrogen gas.



CLASSROOM PROJECTS

Combine this kit with other Renewable Energy kits and work with classmates to assemble models using the components to solve various energy problems in daily life!

Project 1: Construct a sports arena with several solar panels on the roof. Store the sun's energy during the day and use it to light up several LED light modules at night to illuminate the entire arena.

Project 2: Construct a green building that can store electricity generated by wind power and use it to operate electric fans, effectively reducing the classroom's temperature.

Project 3: Use the quick wire connector to connect several wind power generators or solar power generators together, and combine them with the GEMS and supercapacitor. Simulate a wind power station and a solar power station, and use the GEMS to monitor the generated voltage and current values.

Project 4: Combine two generator/motors with fans to create a hand-crank fan.

Integrate data using micro:bit

Please scan the QR code on the right and follow the steps to combine Renewable Energy Lab with Robotics Workshop with micro:bit. Use the micro:bit to monitor and integrate power generation data.

Technical product development: Genius Toys Taiwan Co., Ltd.
Text and editing: Hannah Mintz, Ava Tessitore, and Ted McGuire
Additional graphics and packaging: Dan Freitas
Manual design concept: Atelier Bea Klenk, Berlin
Manual illustrations: Genius Toys Taiwan Co., Ltd. and Thames & Kosmos

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